RIGID LOADING ACCELERATES FULL-SCALE AIRCRAFT FATIGUE TEST

ZHENG Jianjun, WANG Mengmeng, ZHANG Lei, ZHANG Wei

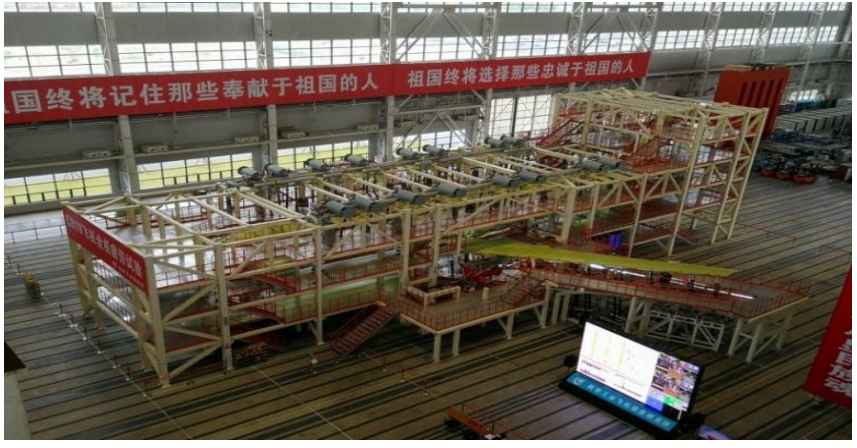
AVIC Aircraft Strength Research Institute of China

Contents

1 FULL-SCALE FATIGUE ACCELERARTION NEEDS

The full-scale aircraft fatigue test is a top-level compliance verification using typical fatigue load spectra to verify whether the design, manufacturing and maintenance of the aircraft can meet the requirements of the airworthiness regulations.

The test results are the fundamental basis for verifying the design and manufacturing conformity of the overall structural fatigue design, as well as the basis for modifying the design, ensuring the operational safety of the in-service fleet and carrying out life extension work.



1 FULL-SCALE FATIGUE ACCELERARTION NEEDS

Design stage based on safety life	Design stage based on fatigue damage tolerance	Design stage based on widespread fatigue damages
Verify **the fatigue design of the overall structure**, and divide the obtained fatigue failure life by the factor of safety of 4.0 as the fatigue life of the aircraft.	Verify that the overall structure can meet **the requirements of fatigue damage tolerance design**, and determine the first inspection threshold (**IT**) and repeat inspection cycle (**RII**).	Determine the effective limiting life (**LOV**) of the overall structure and verify that the aircraft **will not experience widespread fatigue damage before reaching the effective limiting life**.

Validation terms 25.571

Damage tolerance and fatigue assessment of structures

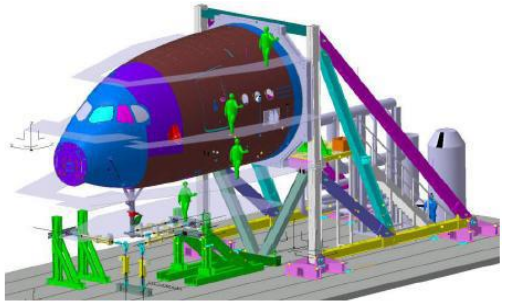
- Sufficient full-scale fatigue testing evidence must be used to demonstrate that there will be no widespread fatigue damage during the design and service life of the aircraft.
- The type certificate can be issued before the completion of the full-scale fatigue test, provided that the airworthiness authority has approved the plan developed to complete the required tests.
- In addition, it is stipulated in the airworthiness limitation part of the continuous airworthiness document required by Article 25.1529 of this part that before the completion of this test, the number of cyclic used by any aircraft shall not exceed half of the cyclic number accumulated on the fatigue test piece.

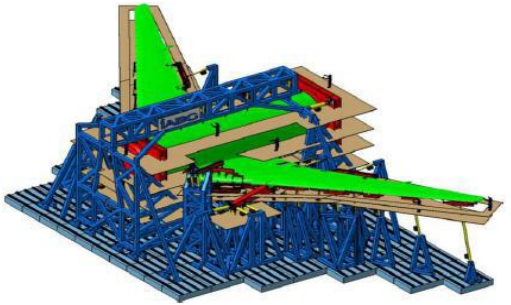
1 FULL-SCALE FATIGUE ACCELERARTION NEEDS

Implied fatigue acceleration demand

Purpose of Aircraft Full-Scale Fatigue Test

1. **Expose** the fatigue weak parts of the body structure, providing experimental basis for structural design and manufacturing process improvement;
2. **Verify** whether the main meets the relevant requirements of widespread fatigue damage (WFD);
3. **Verify** the fatigue characteristics of the main load-bearing components of the body structure, and provide experimental basis for determining the inspection threshold value of the body structure;
4. **Verify** the detection methods for structural cracks and the applicable repair plans in the structural repair manual, providing experimental basis for developing maintenance outlines for aircraft structures;
5. **Verification** of fatigue analysis methods.





1 FULL-SCALE FATIGUE ACCELERARTION NEEDS

Economy is the long-term pursuit in aircraft development

Fatigue test expenses
10 million+/year

Put into operation as soon as possible
100 million+/year

Time is money Efficiency is vital

Contents

2 THE FACTORS AFFECTING FATIGUE TEST

(1) Experiment Scheme

A380 full aircraft fatigue test Complete the 3.2DSG test in 87 months.

ARJ21-700
130.6 months
2 times DSG

MA600
120 months
3 times DSG

A350XWB Returning to the traditional three-stage experiment，Complete fatigue test in 26 months.

Rear fuselage and vertical tail

Approximately 340 cycles per day

Full size composite material cylinder section

Approximately 550 cycles per day

2 THE FACTORS AFFECTING FATIGUE TEST

(2) Test load spectrum

Test load spectrum: The use of weighted spectra can significantly reduce the number of lines in the load spectrum, but **how to achieve equivalence has not yet been fully resolved**.

Civil aircraft

The fatigue test spectra of Airbus A340, and A340-600 all use a 1.1 weighting factor, while A320 uses a 1.15 weighting factor. Shorten the duration of fatigue testing by approximately 30%.

ASRI:

- **Applying equivalent load spectrum and amplified load spectrum to fatigue test loading of a certain component obtained fatigue test results consistent with the comparative test.**
- **Based on the improved DFR method, the equivalent damage conversion of fatigue test load spectrum is applied to the fatigue test of MA600 rear fuselage. After simplification, the total number of cycles in each task segment was significantly reduced, and the number of cycles in important task segments was reduced by about 50%.**

Military aircraft

Both the US Air Navy Joint Use Specification Guide JSSG-2006 and the Chinese National Military Standard GJB 67.6A-2008 recommend the use of the "Durability Severity Spectrum" for aircraft structural life extension.

Some successful application cases of military aircraft in the United States, but different cases provide different severity spectrum coefficients. Currently, there is no consensus on the specific values or rules for severity spectrum.

2 THE FACTORS AFFECTING FATIGUE TEST

(2) Test load spectrum

Test load spectrum: The main acceleration technologies include **low-frequency deletion method, severe spectrum method, amplitude enhancement, and load conversion.**

Comparison of test speeds before and after ARJ load spectrum optimization

No.	Category	Before	After
1	Number of lines in the E-spectrum	303	157
2	Daily cycle	40-50	90-100

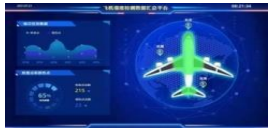
2 THE FACTORS AFFECTING FATIGUE TEST

(3) Damage inspection and maintenance

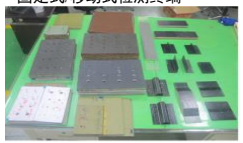
- **Delayed detection of damage and difficulty in detecting critical damage have led to the need for immediate shutdown and maintenance after damage detection, delaying the development cycle**

数字化检测
固定式/移动式检测终端

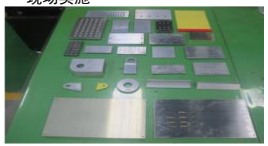
数字化检测
现场实施



数字化检测
检测过程实时显示



通用型复材对比试块



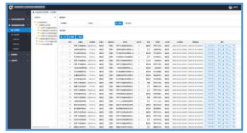
通用型金属对比试块

远场涡流检测技术研究

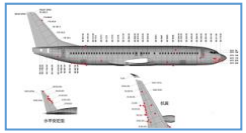
分布式机器视觉检测

裂纹扩展在线检测与测量技术

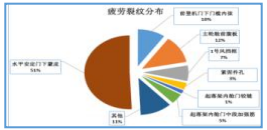
银涂层在线检测研究



飞机结构损伤数据库

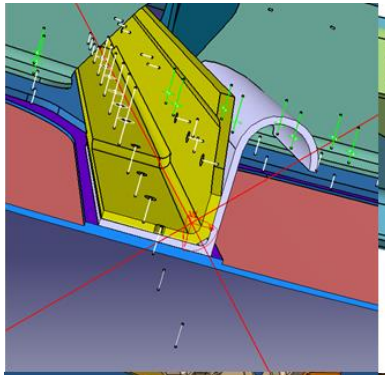


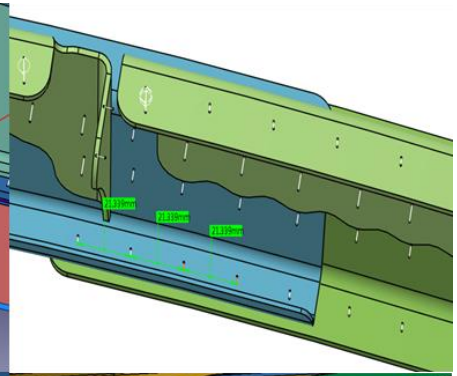
飞机结构损伤统计

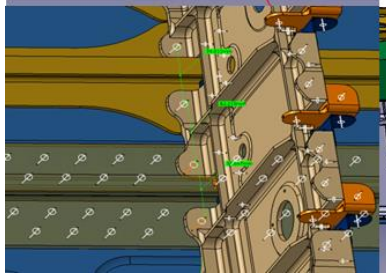


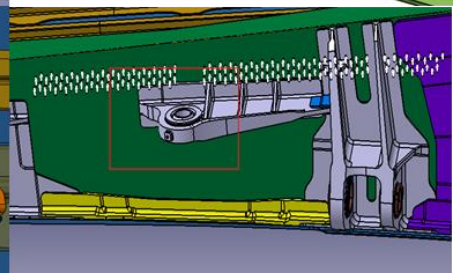
飞机结构损伤分析

- **Unexpected damage is the main reason for delaying the development/implementation cycle of structural maintenance plans**





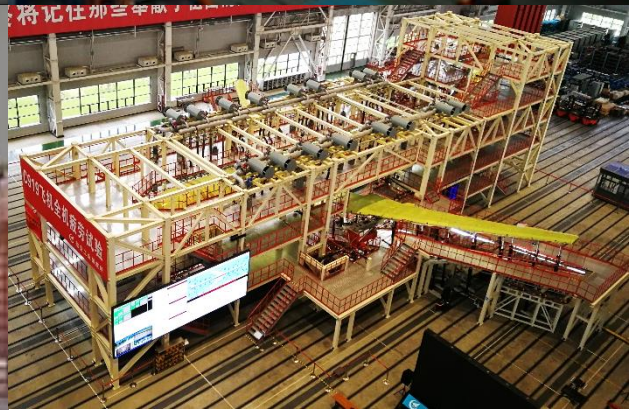




2 THE FACTORS AFFECTING FATIGUE TEST

(4) Test implementation speed

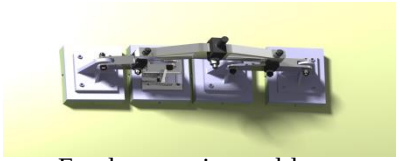
- The experimental loading technology is constantly improving and improving
- The latest testing technology has achieved zero failure in the fatigue full cycle testing system
- The effective testing time for domestic models accounts for about one-third of the total cycle



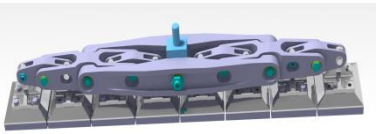
Contents

3 THE RIGID LOADING TECH

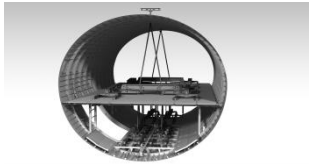
- Hard connection
  - tension pad-lever system
  - floor beam lever system
  - design of actuator
  - connection form
  - oil circuit system
  - pneumatic system



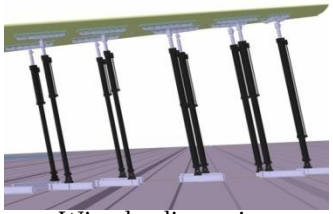
Fuselage tension pad-lever system



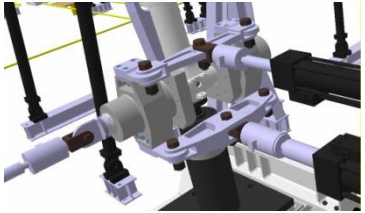
Wing tension pad lever system



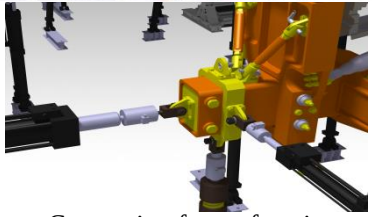
Floor beam lever system



Wing loading point connection form



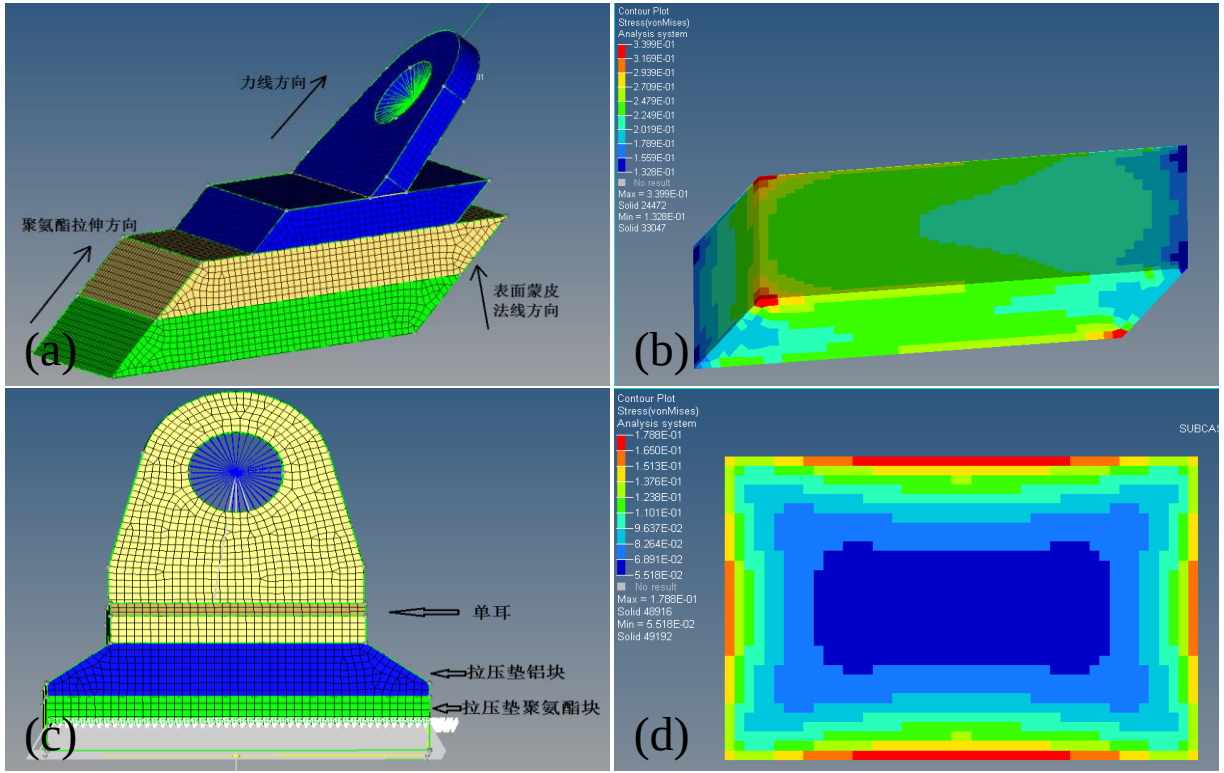
Landing gear loading point connection form



Connection form of engine loading point

3 THE RIGID LOADING TECH

(1) Optimized design and analysis of tension pads



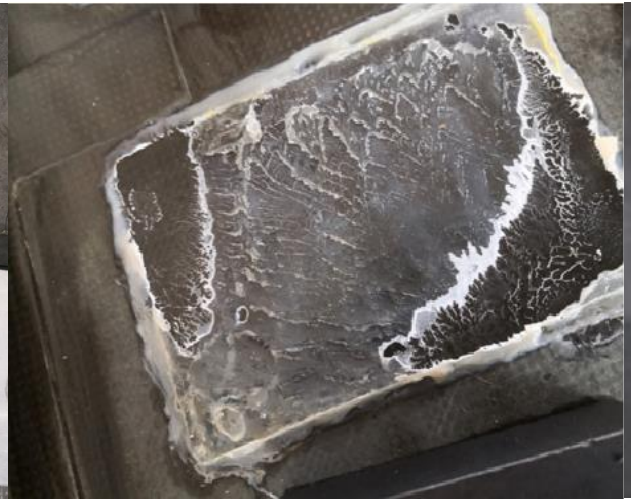
The tensile pad is made of polyurethane , and the surface of the test piece is attached to the test piece according to the shape of the test piece, and the other side is flat and attached to the aluminum plate.

Finite element simulation shows that the maximum stress of the shear loaded tensile block is **0.18 MPa**, which is much smaller than the theoretical damage stress of **35 MPa** of polyurethane material and **meets the safety margin requirement**.

3 THE RIGID LOADING TECH

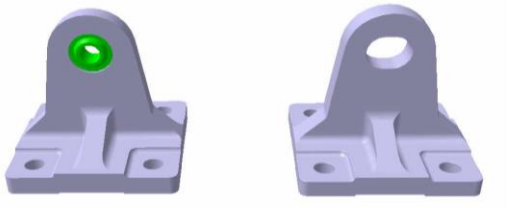
(2) Tensile pad verification test

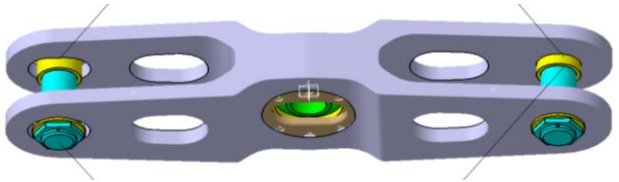
No.	1	2	3	4	5	6	7	11	12	13	14
Failure load (kN)	40.5	28	24	22	41	39	44	8.8	9.8	12	13

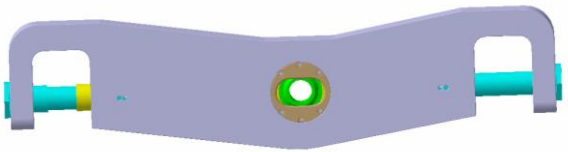


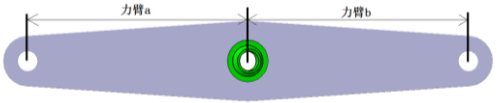
3 THE RIGID LOADING TECH

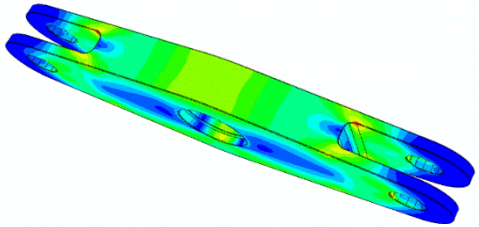
(3) Optimized design of lever systems

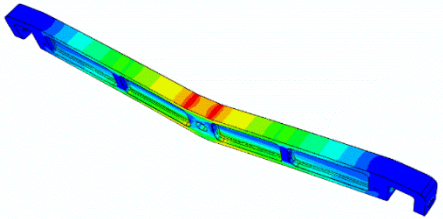












The primary lever

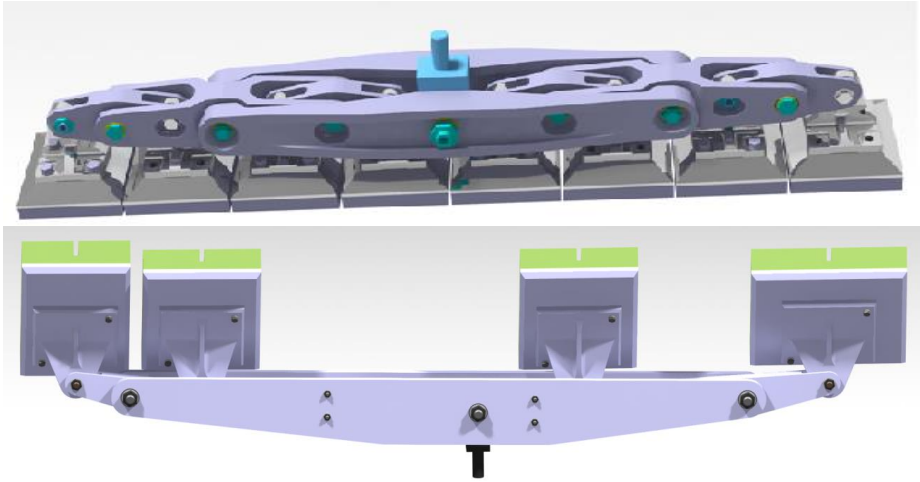
The secondary lever

The final lever

Contents

4 APPLICATIONS OF RIGID LOADING TECH

Tension pad-lever system verification



The results show that the tension pad does not show obvious degradation of performance such as open glue, tearing, loss of elasticity, etc.
The lever system is stable and reliable, and no failure, transitional wear, bolt loosening and other failures are detected.

4 APPLICATIONS OF RIGID LOADING TECH

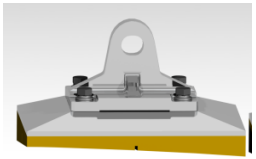
Tension pad-lever system advantages

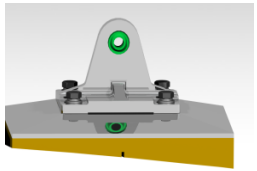
Increase loading rate

Reduce usage and maintenance

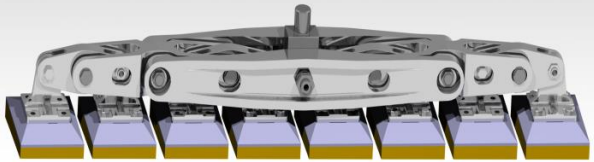
Accurate load simulation

Low number of loading points





Nested same layer tension pad lever system



- ✓ **Multi level lever increasing stability and improving loading accuracy under large deformation.**
- ✓ **Three level linkage adaptive motion making the assessment more realistic.**
- ✓ **The internal power transmission of the system is clear and not stuck.**

4th generation tension pad-lever system

4 APPLICATIONS OF RIGID LOADING TECH

- The new loading system is applied for the first time in the fatigue test of full-scale structure.
- 34 wing vertical loading points, 12 nose/tail vertical loading points and 10 fuselage lateral loading points are arranged symmetrically on both sides and loaded in a synchronized and coordinated manner.

The fatigue test of full-scale structure

Summary

- It is the eternal goal of the test team to improve the fatigue test efficiency under the premise of ensuring test safety and loading accuracy.
- We summarized the technical advances of using tension pad-lever system in full-scale aircraft structural fatigue test and integrate these technologies into full-scale aircraft structural fatigue test.
- The application shows that the rigid loading system runs normally, is stable and reliable in long-term use, has good control accuracy, and the test efficiency is significantly improved compared with previous.
- The successful application of these technologies provides an important reference and support for subsequent fatigue tests of other aircrafts.

Thanks for your attention!

AVIC