CONCEPT OF THE NEW A320 FATIGUE TEST

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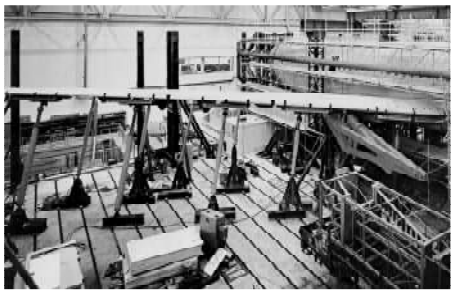
Abstract: Within the scope of the Extended Service Goal (ESG) for the A320 family fleet fatigue tests (NEF) have been decided by Airbus in order to support analysis/justification for an extension of the limit of validity (LoV) of the maintenance program to ensure continuation of safe aircraft operation. Up to 180,000 SF have to be performed to simulate the fatigue and damage tolerance behaviour of the airframe. The concepts of the new fatigue tests have been developed based on the experience and cognitions of all former aircraft tests for Airbus and in particular the A320 EF tests about 20 years ago, when EF2 was accomplished by IABG. Since the new tests have been taken into Airbus` program at very short notice, the realisation of the test set-up required unique and very time efficient solutions in all needs. The paper presents the test concept for the A320 NEF2 & NEF3 and highlights some improvements. The paper thus gives an overview of efficient and state-of-the-art full-scale fatigue testing currently being practised by IABG.

1. HISTORY OF AIRBUS FULL-SCALE FATIGUE TESTS BY IABG

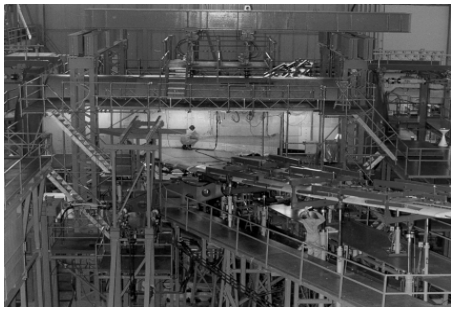
Aircraft structural integrity must be ensured from the first to the last flight. The comprehensive services provided by IABG's aeronautic experts contribute substantially to the safety of aircraft structures. Structural tests are indispensable for the development and certification of aircraft, to guarantee efficient and safe operation in service. IABG's fatigue and strength testing activities are based on the experience which IABG has gained during more than 40 years of aircraft structures testing. Especially the full scale fatigue tests of all main AIRBUS types have been carried out successfully by IABG meeting all requirements of AIRBUS as contractor.

The first full-scale fatigue test started 1973 with the A300. All following AIRBUS aircraft A310, A320, A330/ 340, A340-600 [2], A380 [3] have been tested by IABG. Currently, A320 is undergoing testing again in the frame of the extend service goal (ESG) program. Thus, the A320 centre fuselage and wings will have been tested twice (as EF2 and NEF2) in the course of 20 years. For the first time ever at test of the A320 rear fuselage (NEF3) is currently being performed by IABG simultaneously with the NEF2 test. While these two tests are performed in Ottobrunn near Munich, the test of the A380 is running at the Dresden site of IABG. Moreover, the test for the A400M is under preparation in Dresden.



A300: 1973 – 1980

A310: 1981 – 1985

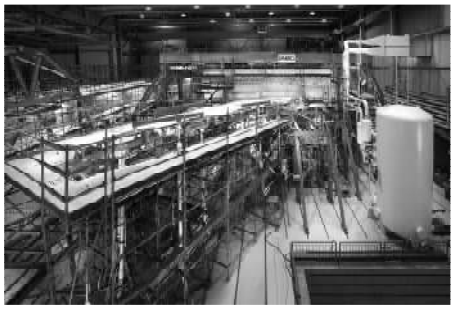


A320: 1986 – 1988

A330/ A340: 1990 – 1996

A340-600: 1998 – 2002

A380: 2003 – 2010



A320 NEF2: 2007 – 2011

A320 NEF3: 2007 – 2011

Figure 1: Airbus Fatigue Tests at IABG

2. BACKGROUND OF A320 ESG PROGRAM

On the strength of 20 years' experience in monitoring more than 3,600 single-aisle aircraft now in service, Airbus is looking to take the A320 Family further. Work towards an extended service goal (ESG) for the family is now well under way with a development test programme, including major full-scale fatigue tests [1]. The overall aim of the A320 Family ESG is to enhance its maintenance programme from the current specification of 48,000 flight cycles (FC) and 60,000 flight hours (FH), up to 90,000FC and 180,000FH respectively. This extension will progress in two steps referred to as 'ESG1' and 'ESG2'.

ESG1 is an initial step planned to become effective in 2010 that will target a service goal extension of 60,000FC and 120,000FH. This programme will achieve a balanced development of structural potential and optimised maintenance activities for the aircraft family through its analyses. The development test phase for ESG1 is being conducted until July 2009. It will involve 120,000 simulated flights, each characterised by operational data monitored and collected to date. Subsequent testing through to 2011 will aim to validate ESG2's ultimate goal of 90,000FC and

180,000FH, and will involve up to 180,000 simulated flights and a total of 360,000 simulated flight hours [1].

To achieve approval for the Extended Service Goal package, Airbus is carrying out full-scale fatigue tests on specially manufactured partial aircraft test sections. The original A320 configuration will be taken into consideration, as well as the specificities of each family type. All of the results will be compiled to show the fatigue behaviour of the complete aircraft family. These tests will take into account 20 years of experience in A320 family operations.

3. TIMELINE OF THE A320 NEF2/ NEF3

The timeline requirements in the A320 ESG program of the preparation phase for the test set-up and fatigue testing phase posed a challenge on IABG by the extremely short lead time. After the project start in March 2007 with the engineering, design and manufacturing phase the first major project milestone was reached with the delivery of both test specimens beginning of January 2008 by Beluga transportation to Munich Airport. After the follow-on works for the final assembly of the test specimens the two test set-ups were completed and the commissioning phase was started as scheduled beginning of July 2008 for NEF3 and September 2008 for NEF2.

The NEF3 fatigue test was started in August 2008 in order to reach the ESG1 milestone of 120,000 simulated flights in July 2009. The NEF2 fatigue test was started in November 2008 in order to reach the ESG1 milestone of 120,000 simulated flights in July 2009 as well. The ESG2 milestone of 180,000 simulated flights shall be completed prior to July 2011 for both NEF2 and NEF3.

End of March 2009 NEF2 had reached 50,000SF while NEF3 was progressing already at 104,000 SF.

4. THE CONCEPT OF THE A320 NEF2 & NEF3 TEST SET-UP

4.1 Test Set Up

The test articles are installed in a test set up consisting of restraint systems, several loading rigs, load distribution and introduction system (loading trees), inspection rigs, the hydraulic and pneumatic loading systems as well as the control and data acquisition systems. Due to the fact that both tests are using the same data acquisition system, hydraulic and pneumatic power, the tests could be placed tightly together in one test laboratory hall.

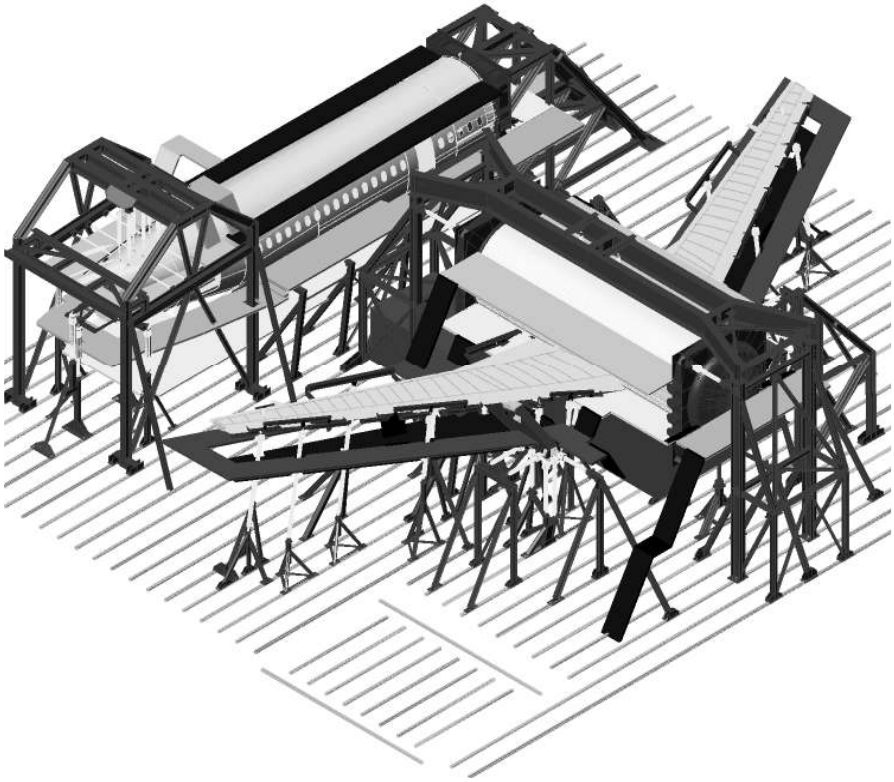


Figure 2 – Isometric view of the A320 NEF2 and NEF3 test set up

The NEF2 test article is supported statically determined by 6 hinged rods of the restraint system blocking all 6 degrees of freedom. The rods are connected at the forward bulkhead constrained in X-, Y- & Z-direction, at the rear bulkhead constrained in Y-direction and at each main landing gear dummy constrained in Z-direction.
The NEF3 test article is rigidly fixed at the bulkhead. This was achieved by welding the bulkhead to a steel ring, which is bolted to the fuselage end. It was necessary to design the restraint rig considering stiffness requirements to avoid large deflection of the 19m freely suspended tail.

A modern test and load introduction concept was developed, which fulfils all given requirements. In total 61 (NEF2) and 33 (NEF3) dual acting servo-hydraulic jacks are installed to the test set up to simulate aerodynamic and inertia loads of the aircraft structure.
The loads will be applied directly either via loading trees to seat and cargo rails, fitting riveted to the structure, pads bonded onto the wings or they are introduced via dummy structures.

Scaffolds are used as inspection rigs. They provide access to all parts of the test article and test systems during inspection, maintenance and repair works. The advantages of using scaffolds instead of a designed inspection rig are:

- minimal effort and costs during the planning (only the inspection levels need to be defined)
- highly flexible rig adaption to the current requirements during the installation phase
- fast dismantling and reinstallation to get access for repair works at the test article
- reuse for future projects

4.2 A Comparison between A320 EF2 and NEF2 Test

As mentioned above, IABG performed the former A320 EF2 test during the late eighties. The dimensions of the former EF2 test article are equal to the NEF2 test article. The past experiences of IABG were used for the dummy design and as concept guideline for the NEF2 test

Therefore the design of the dummies for main landing gear, engine-pylon, slat-track, flap-track, aileron and the bulkheads are based on former EF2 design, taking into account the actual load requirements. The manufacturing costs of fuselage loading trees could be drastically reduced by using welded design instead of former casting design.

There is a significant change in the support of the test article between the former EF2 and today's NEF2 test. The EF2 test article was supported statically determined in the test rig at both bulkheads and after test shut down additionally supported in Z-direction at the main landing gear by a separate loading system thus avoiding undesired specimen stresses. At the NEF2 the Z-support rods were moved from the rear bulkhead to the main landing gear dummies. In this way, no further support system was required.

The wing box loading was adjusted from five jacks at EF2 test to seven jacks at NEF2 test per wing. Two additional jacks are located at the inner wing area to achieve a better torsion moment simulation. The outer wing loading has been shifted from the top wing skin at EF2 test to the lower wing skin at NEF2 test. This concept reduces the moving mass to a minimum at outer wing, which is necessary to achieve a high test speed.

At NEF2 test the volume reduction of the fuselage by styrofoam blocks was not realised. This gives now the flexibility to perform quick inspection in the fuselage without necessity to remove the blocks out of the fuselage for getting access.

4.3 Load Pad Arrangement

The arrangement of load pads has been customized in terms of structural demands and efficiency. The pad groups had been defined such that they follow spars and ribs. Therefore rectangular pad groups were not acceptable. Nevertheless, the pad group still follow a certain standard in order to save time and maintain a high

quality. The figure below shows a pad group with an optimized load distribution onto rib and spar.

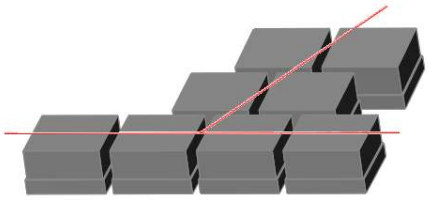


Figure 2: Customized pad layout at the A320NEF2

The tough time schedule of the overall project ended up in a narrow time gap for pad bonding. Therefore the time consuming turning of the wing and/or exclusive provision of the wing at Airbus for pad bonding was not possible. The bonding had to take place after final assembly of the wing to the fuselage and while the assembly of the test rig continued in parallel. In order to fulfil the task the pad bonding had to be done from below with an adapted bonding device to host the individual pad layouts with a high reliability and quality.

Figure 3: Pad Bonding at the A320 NEF test specimen

4.4. CONTROL & MONITORING SYSTEM, DATA ACQUISITION SYSTEM

For actuator control of the tests two different control & monitoring systems (CMS) are used. Based on the complexity the NEF2 is operated by an IABG developed system (70 channels) based on Logidyn components and NEF3 uses a SmarTEST Elite system (40 channels). These systems also control the pressure inside the fuselage. Each control channel is equipped with various monitoring features to guarantee safe test operation. For additional safety, the NEF2 CMS monitors the reactive loads measured by 6 struts and NEF3 CMS the displacements in x- and y-direction of the tail cone.

Compared to the first A320 test, the loading program was much more extended for NEF2 and NEF3:

- NEF2: 165 different flight types with about 7,800 different load cases
- NEF3: 270 different flight types with about 10,000 different load cases.

An FE-model for each of the test structures was used to generate appropriate and optimized control parameters for the load cases within the flights.

Due to the introduction of the innovative IABG-CMS on A340-600 and A380 structural tests, which allows increased test speed, the A320 NEF2 is performed as well with superior speed and excellent load reproduction accuracy. For both test facilities extremely short commissioning times could be achieved, particularly for the optimisation procedure to reach the final test speed.

The central data acquisition system (HBM MGCplus) serves both of the NEF2 and NEF3 tests independently. For cost-efficient use of the DAS-Hardware, up to 3072 strain gauges can be connected via a 3-way connector board to the DAS. The DAS itself is equipped with 1024 (expandable to 1344) strain gauge inputs and 70 inputs for deflection transducers. Changing between 3 configurations – each of it can contain up to 1024 strain gauges– is done by patch cables with multi pin connectors. Data Acquisition is managed by the state of the art software system catman Enterprise, designed especially for multi channel purposes.

The modern nature of fatigue testing demands comprehensive measurements results tailored on the requests of analysis. Therefore different kind of measurement campaigns can be performed. Depending on customer requests all patched sensors can be measured simultaneously and automatically following a list of load cases and load steps or following a flight cycle. Here, both types of measurement yield a data file containing the measured peak values of each load case. For particular requirements, a continuous measurement of all patched sensors can be performed as well. Then, the data file contains not only the peak values of the load cases but includes additionally the entire information during ramp-up and ramp-down of the load.

4.5 Pneumatics, Hydraulic

IABG is using its in-house hydraulic power supply with totally 4,000 l/min capacity. A consumption of 1.100 l/min will be needed when both tests are running. The

dimensioning of the hydraulic pipes was performed according to the experience of former Airbus tests (A300 – A380 EF), due to the fact that the loading program was not available during the conception phase of this challenging time schedule.
A complete new pneumatic power system for both tests was built up within three months. In this time period the conception, the facility purchase (compressor, pipes, etc.), the build of a new hall, the installation and the function tests were performed. Now the pneumatic system fills each of the NEF2 and NEF3 fuselage up to 564 mbar differential pressure in less than 10 sec.

5. TEST PERFORMANCE

5.1 Test Speed

The loading program consists of 106 loading points for an average NEF2 flight and 83 loading points for an average NEF3 flights. After optimisation of the complete test set up an average test speed of 700 flights/day at NEF2 and 640 flights/day at NEF3 could be reached. Compared to the original requested test speed, the achieved test speed is at NEF2 14% and at NEF3 even 38% faster. The NEF2 test is a factor 2.1 faster compared to the former EF2 test.

5.2 Inspection Procedure

The schematic view below shows the basic procedure of the inspection process. The inspection process is managed by the inspection administration which is responsible for the whole inspection process and the preparation of the inspection job cards.

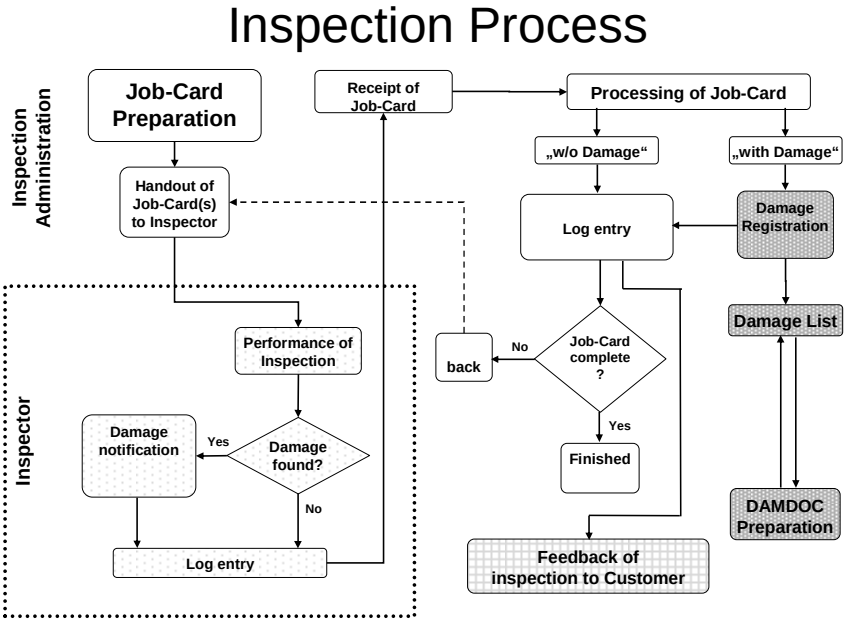


Figure 4: Schematic view of the Inspection Process

5.3 Non Destructive Testing

The aircraft structure of the A320 NEF2 and A320 NEF3 is intensively inspected by IABG (up to level 3/ DIN EN 4179) in regular intervals with latest inspection equipment. The task is to find damages in an early state and to monitor damage propagation closely.

The inspections of the A320 NEF2 and A320 NEF3 are organized in the same manner and are divided in four intervals with different inspection focus:

- A inspection / daily visual inspection combined with monitoring of damages or special areas by visual inspection or NDT techniques
- B inspection / in scheduled intervals with a mix of visual inspection and NDT inspection
- C inspection / alternating with the B-Inspection with an increased NDT inspection and visual inspection effort
- D inspection / intensive visual and NDT inspection at test end

Figure 5: Eddy current inspection on the A320 NEF2 wing

The used NDT methods have been selected based on the inspection task and the structure requirements. The following methods are being practised:

- General and Detailed Visual Inspection (GVI & DVI)
- Ultra Sonic Testing (UT) including Phased Array Ultrasonic Testing (PAUT)

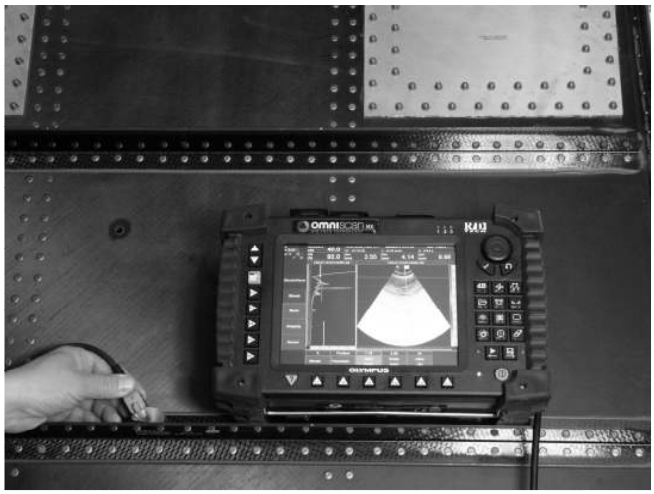


Figure 6: Ultra sonic inspection (PAUT)

- High and Low Frequency Eddy current Testing (HFET & LFET) including usage of four frequency eddy current testing for lap joints (LFET) and bore holes with rotating probes
- X-Ray Testing (RT)

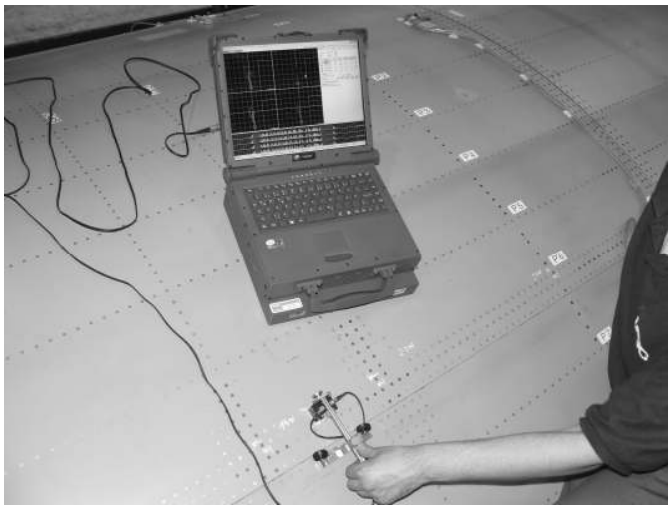


Figure 7: Lap joint inspection with Eddymax 4U (LFET)

5.4 Damage Detection and Documentation

The inspection results are documented using the IABG software DamDoc^{V3}. The SQL server based development is tailored for fatigue testing and seamlessly connects the inspection database with the inspection results in order to provide a complete damage documentation solution.

The database is multi user capable and generates fast and economic documentations and overview of inspection results in order to give Airbus an early view for in time evaluations and conclusions.

Figure 8: Damage Documentation Database DamDoc^{V3}

6. CONCLUSION

For the Extended Service Goal (ESG) program of the A320 Family, two major airframe tests for the center fuselage with wings (NEF2) and the rear fuselage (NEF3) have been erected at IABG Ottobrunn, Germany. Within 9 months, the entire engineering, design and a considerable part of mechanical test set-up build was completed in order to integrate the two test structures in time. Further integration, instrumentation and commissioning could be completed in a second compact time frame. Since July 2008 (NEF3) and September 2008 (NEF2), respectively, both tests are progressing at a fast rate. Test completion is planned for 2011. The extraordinarily successful achievement of densely packed milestones up to the current date was enabled by an efficient mix of proven technologies and procedures and newly established advancements.

7. REFERENCES

[1] Airbus Letter November 2008

[2] A340-600 Full Scale Fatigue Test: A Further step forward into a efficient structure qualification, Olaf Tusch & Klaus Woithe, ICAF 2001 –Volume II, 27-29 June 2001, Toulouse, France

[3] An efficient load introduction concept for the A380 full scale fatigue test, Felix Schwarberg & Frank Eichelbaum, ICAF 2005 Volume I, 6-10 June 2005, Hamburg, Germany