Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE

Review of aeronautical fatigue investigations in France during the period May 2011- April 2013

TECHNICAL NOTE

N°13-DGATA-ST-870001-1 F-A

DIRECTION GENERALE DE L'ARMEMENT

DGA Techniques aéronautiques

DIRECTION GÉNÉRALE DE L'ARMEMENT

DGA Aeronautical Systems

Division : ST

Review of aeronautical fatigue investigations in France during the period May 2011- April 2013

TECHNICAL NOTE

N°13-DGATA-ST-870001-1 F-A

	NAME	Visa	Date	Title
Prepared by	Th. ANSART		10/04/2013	Head of Structures Division ICAF French Delegate

Direction générale de l'armement
DGA Techniques aéronautiques
47 rue Saint-Jean - BP n°93123 - 31131 BALMA Cedex - FRANCE
Téléphone : +33 (0)5.62.57.57.57 – Télécopie : +33 (0)5.62.57.54.47

PAGE WITHOUT TEXT

RÉPUBLIQUE FRANÇAISE
Liberté • Égalité • Fraternité

MINISTÈRE DE LA DÉFENSE

DIRECTION GÉNÉRALE DE L'ARMEMENT

DGA Aeronautical Systems

TECHNICAL NOTE	
Title	**Review of aeronautical fatigue investigations in France during the period May 2011- April 2013**
Reference	**13-DGATA-ST-870001-1 F-A**
Customer	N/A
Task sheet number	N/A
Date of issue task sheet or contract	N/A

CLASSIFICATION	☒ **NON PROTECTED**
Archive duration : technical note storage duration is the life duration of tested equipment	

Declassification		**Testing**	
☒	Descriptive card	Location	DGA Aeronautical Systems
☐	From N/A	Start	N/A
☐	On issuer order	End	N/A

Reference of the security appendix	OP N°	AS N°	du

Contents of the technical note	26 Pages incl.	- Illustration(s)	- Appendix(s)	- File(s)	- Film(s)	- Photo(s)	- CD(s)
Author(s) :	Th. ANSARTTh. ANSART		Key words :	Fatigue, structure, ICAF			

Professions	Poles
2- Aeronautical platforms and aeronautical systems	2- Aeronautical systems architectures and techniques

Government contract : Yes ☐ No ☒	Note available in Indigo : Yes ☒ No ☐

Abstract :

The present review, prepared for the purpose of the 33th ICAF conference to be held in Jerusalem (Israel), on 3-4 June 2013, summarises works performed in France in the field of aeronautical fatigue, over the period May 2011-April 2013.

Topics are arranged from basic investigations up to full-scale fatigue tests.

References, when available, are mentioned at the end of each topic.

Correspondents who helped to collect the information needed for this review in their own organisations are :

- Bertrand Journet for EADS Innovation Works
- Alain Santgerma for Airbus France
- Dominique Tougard, Frédéric Desbordes, Julien Servières and Eric Garrigues for Dassault Aviation
- Pierre Madelpech for DGA Techniques aéronautiques.

Direction générale de l'armement
DGA Techniques aéronautiques
47 rue Saint-Jean - BP n°93123 - 31131 BALMA Cedex - FRANCE
Téléphone : +33 (0)5.62.57.57.57 – Télécopie : +33 (0)5.62.57.54.47

PAGE WITHOUT TEXT

- TABLE OF CONTENTS -

Pages n°

- TABLE OF CONTENTS -

Pages n°

1. INTRODUCTION AND ACKNOWLEDGMENT

The present review, prepared for the purpose of the 33th ICAF conference to be held in Jerusalem (Israel), on 3-4 June 2013, summarises works performed in France in the field of aeronautical fatigue, over the period May 2011-April 2013.

Topics are arranged from basic investigations up to full-scale fatigue tests.

References, when available, are mentioned at the end of each topic.

Correspondents who helped to collect the information needed for this review in their own organisations are :

- Bertrand Journet for EADS Innovation Works
- Alain Santgerma for Airbus France
- Dominique Tougard, Frédéric Desbordes, Julien Servières and Eric Garrigues for Dassault Aviation
- Pierre Madelpech for DGA Techniques aéronautiques.

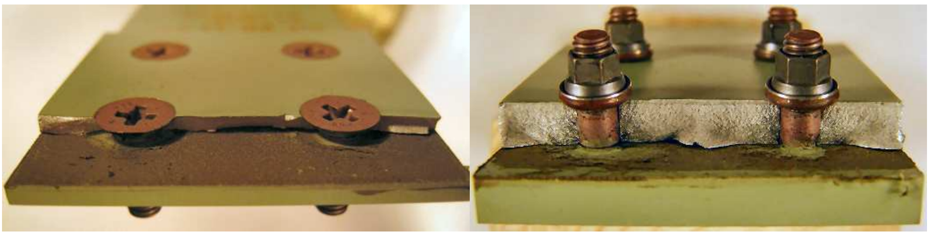
They will be the right point of contact for any further information on the presented topics.

Many thanks to all of them for their contribution.

2. FATIGUE LIFE PREDICTION STUDIES AND FRACTURE MECHANICS

2.1. DIRCAM : ELEMENTARY FATIGUE TESTS PROGRAM FOR IMPROVEMENT OF SIZING CRITERIA AND REDUCTION OF ASSEMBLY COSTS (DASSAULT AVIATION)

An important program of elementary fatigue tests has been performed on metallic joints samples in order to improve the comprehension of fatigue behaviour. More precisely, the aim of this campaign was to define which geometric/assembly parameters are significant and active on fatigue life.



Example of fatigue tests results

The program has been focused on aluminum single shear lap joints assembled with titanium screws/rivets and tested under constant amplitude fatigue spectrum (R=0.1). The test matrix has been divided in three main tasks, one for each potential influent parameter : interference/clearance between hole and screw/rivet, pre-tension in the bolt and gap at the interface between parts after assembly. In each of these cases, the objective was *to improve our methodology of fatigue substantiation so as to take into account these parameters explicitly*.

As a general conclusion, these important results allowed:

- to improve the substantiation methodologies and associated fatigue criteria
- to enlarge the design tolerances to a certain extent to simplify the assembly procedures and allow the process to be more cost effective,
- to understand better the behaviour of some new blind rivets (static+fatigue) for industrial use.

2.2. RESIDUAL STRESS EFFECTS ON FATIGUE CRACK GROWTH OF FRICTION STIR WELDED ALLOYS (EADS IW)

This topic dealing with residual stress addresses the use of standard coupons in fatigue crack growth characterisation of friction stir welded alloys [1].

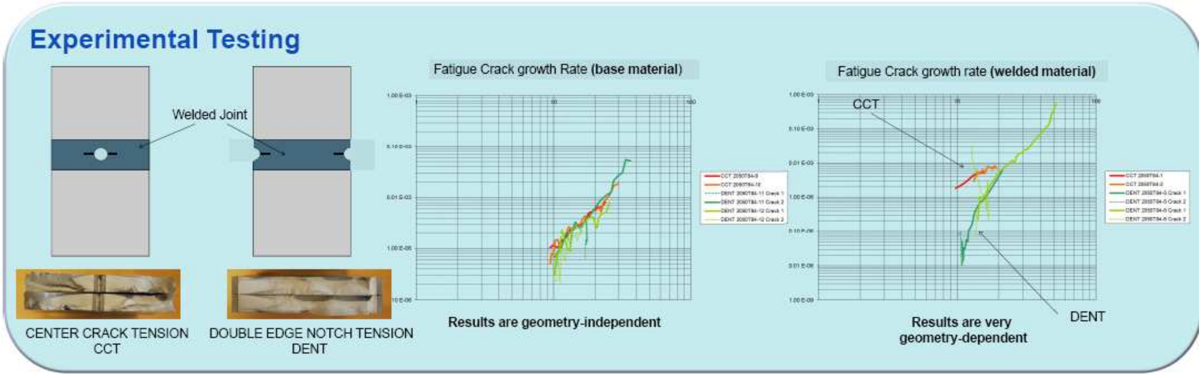
The crack is in the middle and parallel to the weld seam. Due to the machining of the specimen out of the welded plates that takes matter out, residual stress redistribution occurs. The question is: is there any influence of the specimen geometry on the test results due to the residual stress redistribution ?

The alloy under investigation is 2050. Two types of specimen geometries were investigated: a DENT (Double Edge Notch Tension) geometry with a crack at each edge, a CCT (Center Crack Tension) geometry with a central crack.

Constant amplitude loading fatigue crack growth tests were run on the base 2050 at R=0.1 on both geometries : as expected, the fatigue crack growth rate (FCGR) vs applied ΔK curves overlap. DENT and CCT specimens were machined out of FSWelded plates of 2050 with the cracks in the middle of the seam and parallel to it. Testing with the same conditions on the welded specimens shows that the FCGR on the DENT and CCT specimens do not overlap by a significant difference when ΔK is between 10 and 20 MPa√m : the FCGR is much faster on the CCT sample.

Thermomechanical finite element simulations of the FSW process were performed to get the residual stress in the FSWelded plates of 2050 alloy. The FSW experiments were monitored in order to calibrate the input power and heat exchanges for the simulations. Then the machining of the DENT and CCT specimens was simulated using FE calculations to analyse the stress redistribution due to extracting blanks and also due to introducing the cracks.

The FE simulations show that, ahead of the crack tip, the residual stress is tensile for the CCT geometry and it is compressive for the DENT geometry. This may explain why such a difference in FCGR may be obtained. There is then an influence of the laboratory specimen geometry on the fatigue growth behaviour of cracks in welds. Caution must then be taken before using laboratory test data for structural application. It is recommended to use a specimen geometry that is close to the structural geometry and cracking scenario.



[1] D. Deloison, S. Gourdet, F. Marie, B. Journet : Influence of Geometry of Friction-Stir-Welded Specimens on Fatigue Crack Growth Properties. Poster presented at the International Conference on Fatigue Damage of Structural Materials IX, Cape Cod - Hyannis, Massachusetts, U.S.A., Sept. 16-21 2012.

2.3. RESIDUAL FATIGUE LIFE PREDICTION OF CORRODED SPECIMENS (EADS IW)

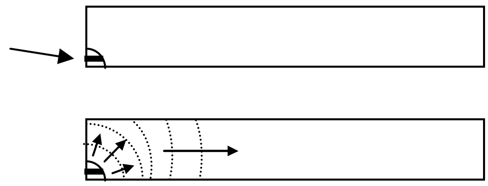
In the area of pre-corrosion, a methodology was implemented to estimate the residual fatigue lives of corroded samples made out of 7075 alloy. The methodology is based on fracture mechanics with the conservative assumption that the fatigue initiation life is reduced to zero due to the presence of the corrosion flaw, as if the flaw were behaving like a crack ready to grow. Therefore the residual fatigue life is a fatigue propagation life.

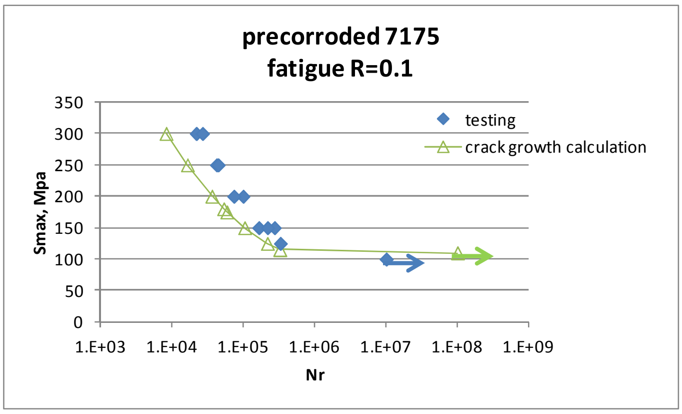
The samples are flat fatigue specimens with a rectangular cross section. The corrosion flaws are pits that have been produced at one corner. Fatigue test have been run at R=0.1 on the pre-corroded samples in air.

The fractographic examination of the fracture surface shows that, on average, a fatigue corner crack with a radius of 200 µm initiates from the corroded corner area. Fatigue crack growth calculations were made with a starting corner crack size with a radius of 200 µm and different values of maximum fatigue stress Smax at R=0.1. The number of cycles to drive the crack from the initial size until unstability is then taken as the residual fatigue life. The fatigue crack growth law that is used in the calculations includes a short crack behaviour when the crack size is below 500 µm. The comparison with the experimental data shows that the method gives a fairly reasonable conservative estimate of the residual fatigue life.

Fatigue crack initiation around a corrosion flaw and taking a quarter circle shape with a radius of 200µm.

Fatigue crack growth





2.4. EFFECT OF TENSILE RESIDUAL STRESS ON STRUCTURAL DETAILS FATIGUE BEHAVIOUR (EADS IW)

In the area of residual stress, one project focused on the effect of tensile residual stress on the fatigue behaviour of technological coupons made out of an aluminium alloy. The tensile residual stress is due to the occurrence of plastic deformation in a stress concentration area, in relationship with severe loading applications. This work was carried out at the request of Airbus. The objective of EADS IW contribution was to use finite element analysis to define how the coupon must be plastically deformed under bending in order to induce the targeted residual stress as in the structural detail and then to run the fatigue tests under tensile loading. Fatigue tests have been run and the results show a reduction in the fatigue life as expected compared to specimens tested without any residual stress. Further analysis is under progress.

2.5. 3D CRACKING (DGA AERONAUTICAL SYSTEMS)

In many of countries, the Air Forces are faced to ageing of their aircrafts. With decreasing budgets, dwindling and delaying new aircraft development, the growing aging aircraft inventory has increased the interest in the reliable analysis of any damage occurring in aircraft structures. Two of the main needs to assess a damage tolerance approach, particularly for massive components such as spars, gear struts or thick lugs, are to develop a capability in 3D crack growth modelling and residual strength determination.

DGA Aeronautical systems in collaboration with German WIWeB launched a study to better understand the phenomena on classical configurations and to assess the traditional computation methods and tools.

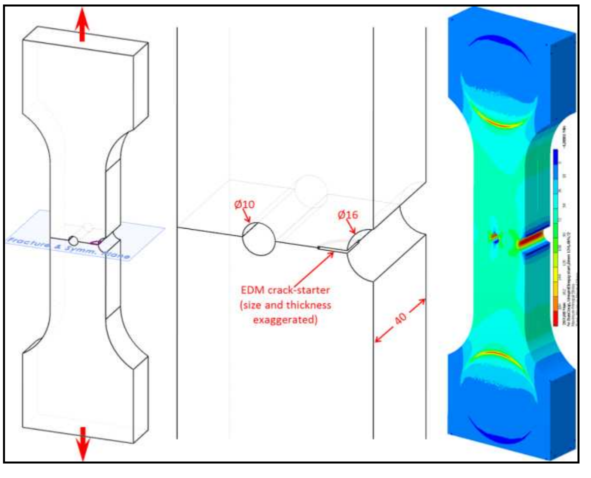
In general, the main difficulties associated with 3D crack growth analysis in order to assess a damage tolerance approach can be grouped into three categories :

- Tests issues to follow the crack in the core of the material in order to calibrate and assess the good correlation between 3D crack growth computation and test results,
- Modelling issues concerning accurate calculation of stress intensity factors along a 3D crack front embedded in a component with complex geometry. Especially at free surface where the stress state is complex and numerically tricky to appreciate.
- Effective determination of the crack growth rate in 3D space and choice of a predictive crack growth law. This can be assessed in terms of shape prediction.
- Use an appropriate criterion to assess the residual stress of the cracked part.

In a first time, empirical techniques enabling to mark the crack front shape in a massive part at different steps of the crack propagation have been investigated. These techniques are assessed on standards coupons CT(80) and CCT(200) which allow to identify classical parameters of crack propagation laws and to assess the influence of the tested marking technique on the overall crack growth rate. All these test results and their interpretations have been used for the second test campaign led on specific coupons with a corner crack.

Crack front follow up with marking techniques

The second part of this study deals with tests and modelling results conducted on specific coupons designed in order to take into account 3D effects on crack propagation. These coupons, notched bars with a corner crack in the depths of the notch, have been designed such as they are representative of 3D effects with a non-uniform stress field on the propagation path and with a quite simple geometry. The retained simple geometry, not too far from a corner crack in a simple bar, will enable to tackle the second challenge of 3D cracks, i.e. predict the global behaviour of the crack. Those tests results will be compared obtained with a rapid FEM solution in order to see the performance and also the limitations.



Specimen geometry and model

First results indicated that the crack propagation law cannot be simply transpose on the first stages of propagation (opening effect) and that the stress intensity factors singularity at the free edge has to be properly taken into account.

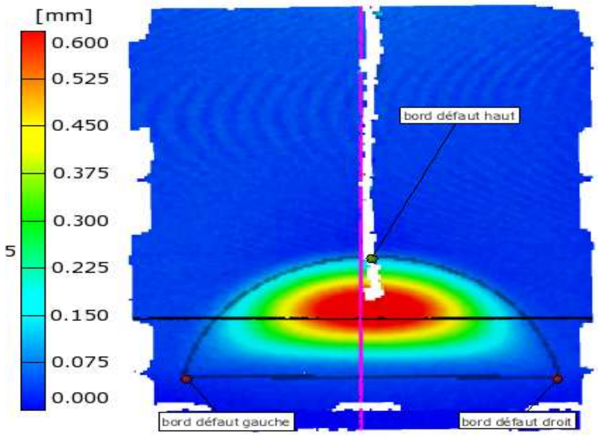
The continuation of the study will be some more finite elements modelling methods testing with different approaches (energetic), but also some analytical ones (Nasgro, Afgrow…). A demonstration on a representative piece of structure with a realistic loading spectrum will be finally performed.

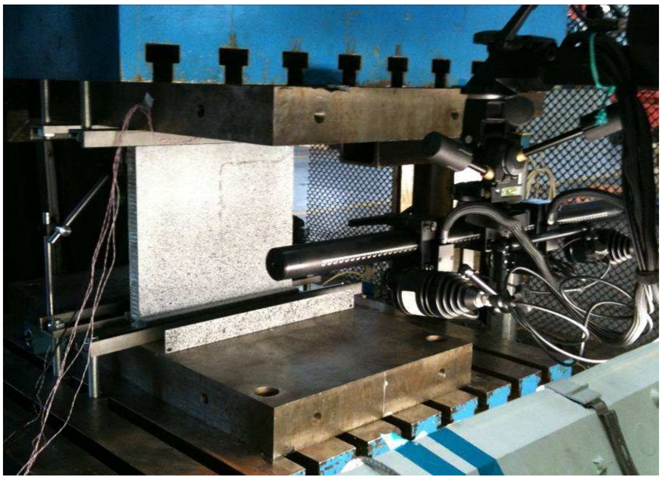
2.6. DETERMINATION OF ACCEPTABLE DISBOND SIZE ON METALLIC SANDWICH (DGA AERONAUTICAL SYSTEMS)

On Bréguet Atlantique 2 (ATL2), wing and fuselage skins are made of metallic sandwich. Experience on ATL1 has shown that water infiltration can cause disbonds inside the structure, but measured propagations were slow and stable.

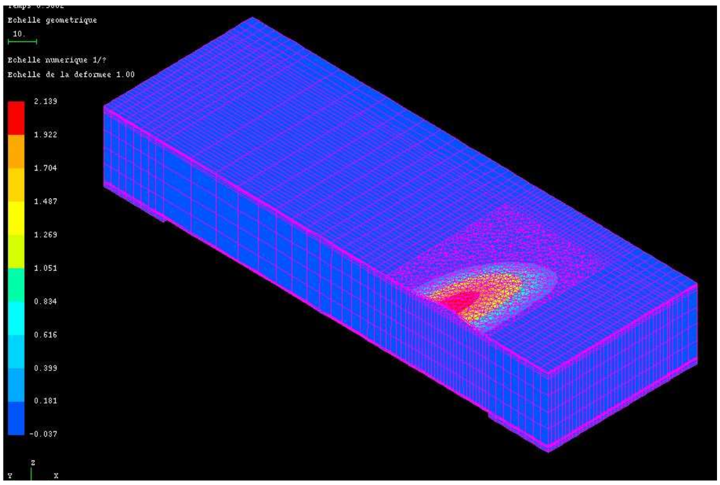
The idea was to introduce an inspection program in the maintenance to prevent a catastrophic size of disbond to occur. To obtain the critical size, the first attempt was to consider the buckling of the disbonded sheet of metal, but it leads to too small sizes for thin panel at the wing tip.

A test campaign on representative coupons of sandwich in compression was performed. Different sizes of disbonds and different thicknesses of metal sheets were investigated. The evolution of the disbond was detected by stereo-correlation and strain gauges. The retained criterion was the non propagation of the disbond.

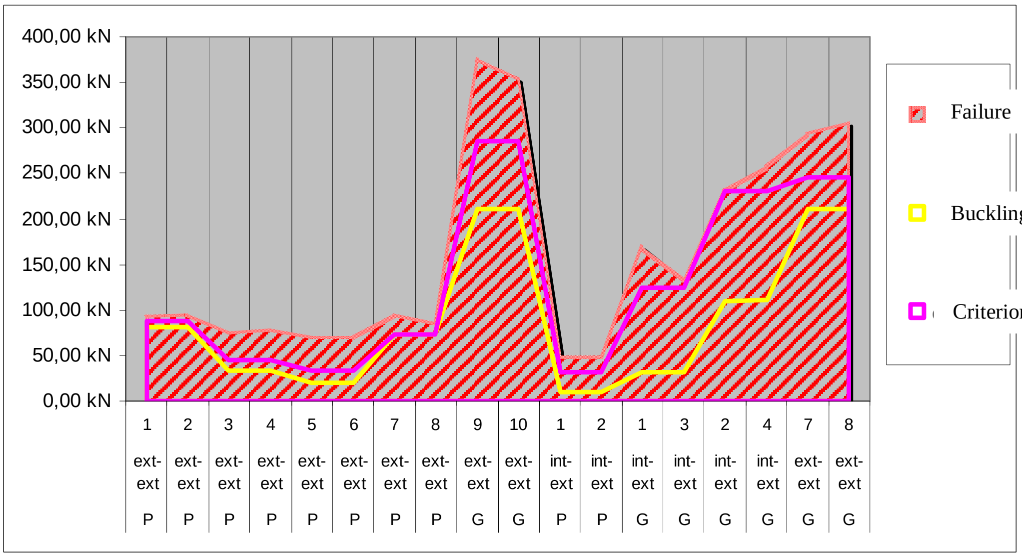




As expected, the failure occurs at higher loads than local buckling. To extend the test results to every configurations of the aircraft structure, a finite element model of the coupons were performed, using a non-linear solver Samcef-Mecano to catch the post-buckling phase of the loading.



Looking at the peel stress in the adhesive, it was possible to correlate the results. It enables to consequently increase the allowable sizes of disbonds, which results in significant increase of the inspection intervals.



3. DEMONSTRATION OF COMPLIANCE TO AIRWORTHINESS REGULATION

3.1. SHOWING COMPLIANCE WITH WFD REGULATION (AIRBUS)

FAR §26.21 was issued end 2010, requiring the Type Certificate Holders to evaluate aircraft structures for Widespread Fatigue Damage (WFD) and publish a Limit Of Validity (LOV) in their Airworthiness Limitation Section. An extensive work performed by AIRBUS over the last 20 years on the WFD topic has come to an interpretation of this new regulation for application to its products.

The Airbus philosophy of aircraft operational life management is based on in-service experience, Full-Scale Fatigue Testing, experience gathered from research and life extension exercises.

Extensive Widespread Fatigue Damage evaluations have already been performed since 1990's according to the draft AC for WFD and based on FAR §26 since Jan 2011. Methodic WFD evaluations have already been performed for A300, A310, A340 and A320 before FAR §26 has been released.

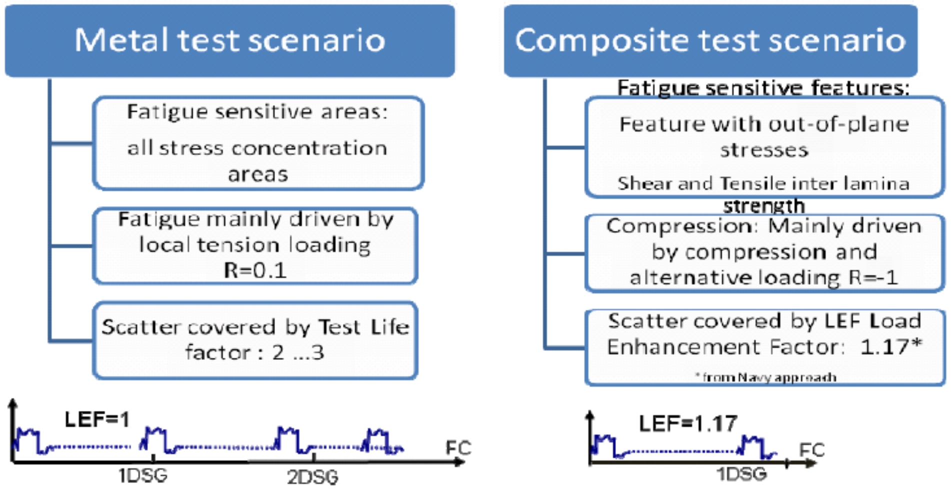
Systematic Barrel- and Full-Scale Fatigue testing has been performed for all AIRBUS products up to at least 2.5 DSG in the concept and design phase. This represents a philosophy of anticipation and ensures a robust design, a sound basis for the maintenance programmes of the AIRBUS products and an efficient means to preclude Widespread Fatigue Damage.

The traditional philosophy of confining the operational life of all AIRBUS models in the ALS part2 ensures full transparency on the limitations of the engineering data that support the structural maintenance programmes towards the operators and authorities at any time. Thus the AIRBUS operational life management has already been aligned with the spirit of FAR §26 before the rule was issued. For A300 model, complementary evaluations to the WFD assessment performed in frame of life extension have been performed to show compliance with FAR §26.21. The $LOV_{PRE\text{-}FAR26}$ (established for life extension) becomes LOV_{FAR26} and a revised set of ALS and Service Bulletins to preclude WFD up to LOV_{FAR26} have been published. Due to the upfront cross-programme approach and additional new development testing the A320-200 WFD evaluation could be completed such that the engineering data to support FAR §26 compliance are already in place three years ahead of the legal compliance date. Due to the robust AIRBUS Single Aisle family structural design it has been demonstrated with the new tests that the airframe is capable of operation even well beyond DSG. A320-200 ESG has been justified with a ‚light‘ structure modification package and a significant relaxation of the maintenance programme and only a few number of WFD maintenance actions have been defined to reach ESG (14 inspections, 4 structural modifications). Performing the new test was an excellent means to optimize the maintenance programme in the light of the large Single Aisle fleet.

3.2. TESTING HYBRID AIRCRAFT IN FATIGUE (AIRBUS)

Composite and metallic parts can be found all over the aircraft. It is therefore not possible to group them apart from each other during the validation by full scale testing. Either two full aircraft structures need to be used for demonstration or the approaches used for this need to be combined.

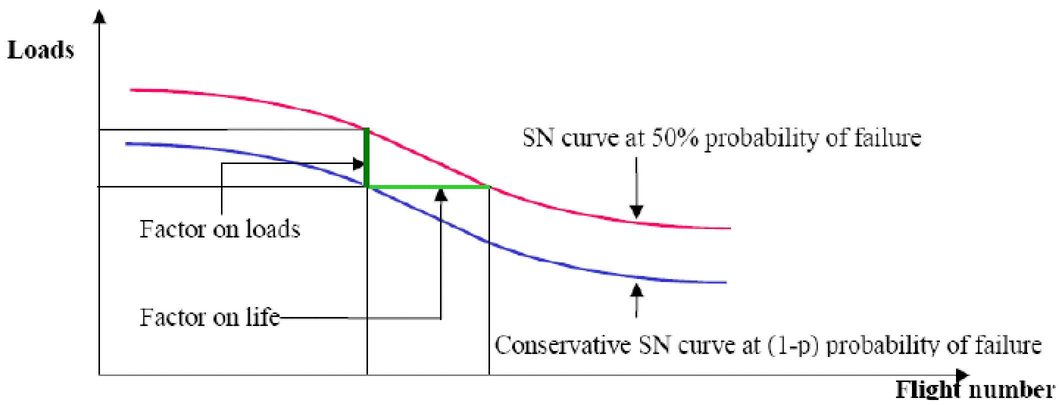
Main differences between the fatigue behaviour of composite and metallic components are in terms of specific sensitive features, loading and scatter. Work performed was to review how the original Load Enhancement Factor concept was derived and its possible adaptation required to address current issues of composite fatigue, and, finally, to propose solutions towards enabling the full scale fatigue testing for composite and metallic components in a unique test cell.



To combine the composite and metallic testing specificities in a unique test cell, it is necessary to sort out three main differences: difference in fatigue sensitive features, different fatigue sensitive loading, difference LEF/LF factors.

The test engineering progresses allow to find test means to deal with the two first points. It is currently possible to distribute the loading all over the structure in such a way that both metal and composite part would be loaded in representative manner with alternate tension and compression loadings.

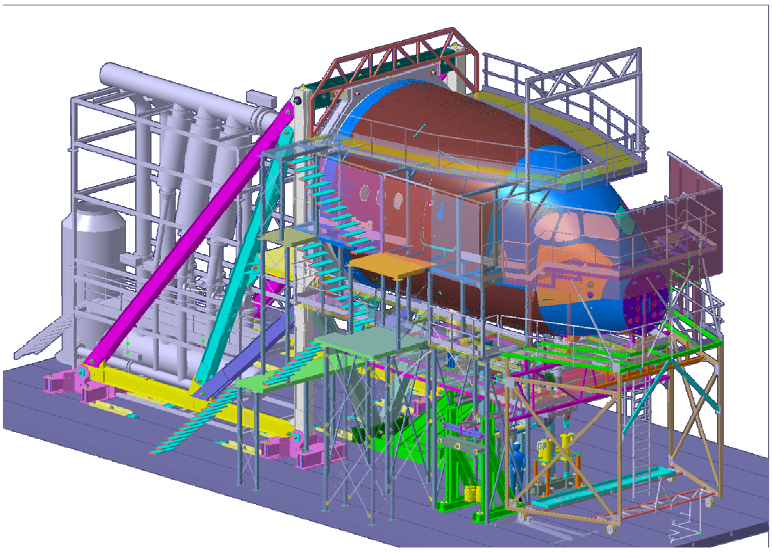
The third discrepancy concerns the Load Enhancement and Life Factors to be applied to cover the scatter. Some compromises have been identified on the Composite LEF factor that could be combine with a Life factor approach. A life factor of 2.5, combine with a LEF of 1.02 should be a good compromise to fulfil Metallic as Composite requirements.



4. FULL-SCALE FATIGUE TESTS, LIFE EXTENSION, FLEET MONITORING & MANAGEMENT

4.1. AIRBUS FULL-SCALE FATIGUE TESTING (AIRBUS AND DGA AERONAUTICAL SYSTEMS)

The preparation phase for A350 major fatigue tests is going on. Full-Scale fatigue tests will be performed for metallic structure as well as for composite structure. Forward fuselage fatigue test will be performed in DGA Aeronautical Systems test facilities.



Test specimen was just delivered and fatigue test is expected to start at mid-2013.

As part of the life extension of the A320 family, a new Full-Scale Fatigue Test was performed. The 3 tested specimens i.e. forward fuselage (tested at DGA Techniques aéronautiques), centre fuselage & wing, rear fuselage reached their test target of 180,000 simulated Flight Cycles (see previous ICAF review).

Forward fuselage is now performing the last testing cases : residual static cases.

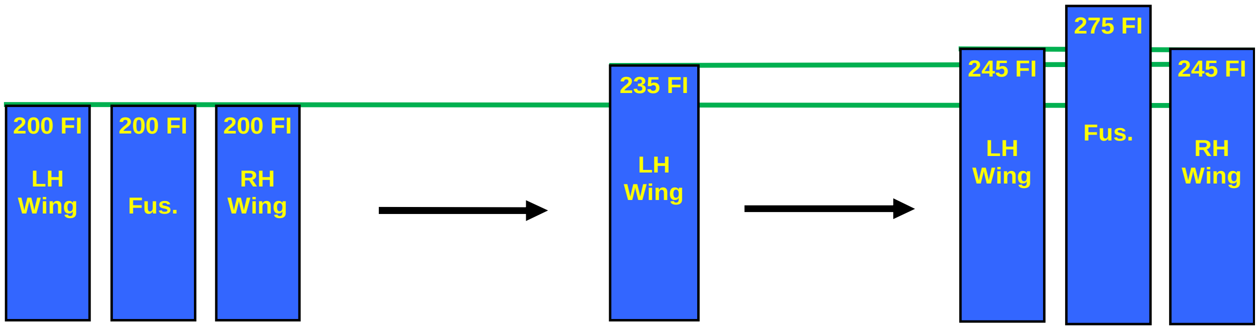
4.2. MIRAGE 2000 FIGHTER AIRCRAFT LIFE EXTENSION PROGRAM (DASSAULT AVIATION AND DGA AERONAUTICAL SYSTEMS)

A full-scale fatigue test has been carried out in the DGA Aeronautical Test facilities on the aged airframe of an aircraft retired from the French Air Force fleet.

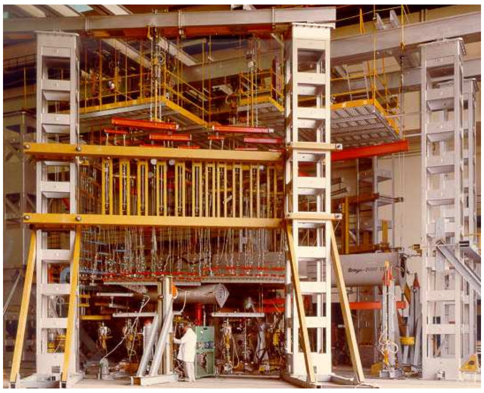
Only "light" repairs have been implemented and have been validated through the test.

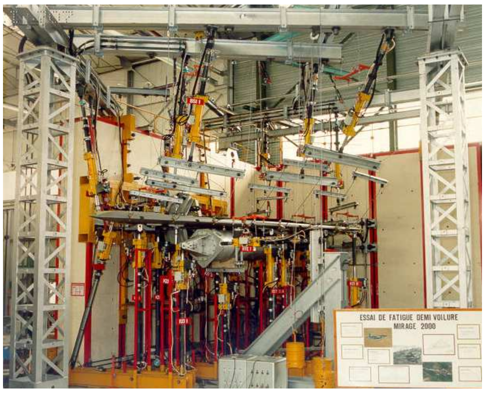
Mirage 2000 specific Non Destructive Control systems have been validated.

Details of this life extension test can be found in previous ICAF reviews. However a summary of tests performed and fatigue index demonstrated is recalled below.



CEF1 : 1st Airframe Test (1981-1984) | **Reinforced Wing Box Test (1992-1994)** | **CEF2 : 2nd Airframe Test (2005-2010)**



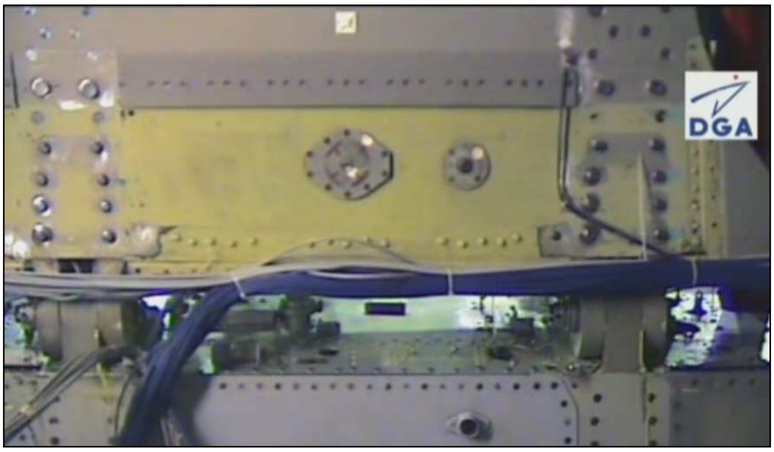


Safe Life directly validated by the full-scale fatigue tests

After fatigue phase, 7 ultimate load cases (sizing wing box, fuselage, landing gears attachments and cockpit) have been successfully applied on the test specimen.

A final margin research (corresponding to the most severe flight manoeuvre) has been achieved, until right wing box failure, 8 % above the ultimate load :

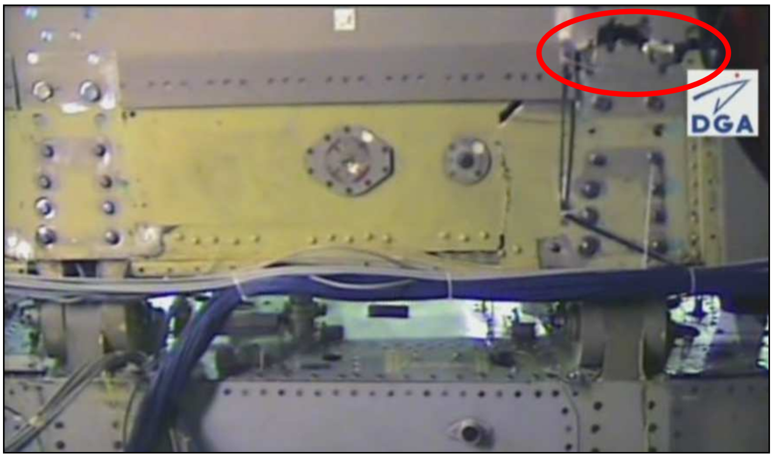
Wing Box



Fuselage

Rear Main attachment **Front Main attachment**

Failure of the front main spar lower flange, close to the attachment :



Final investigations are under achievement: control of the most critical areas of the airframe, with destructive methods (particularly, repaired areas and bores of the wing box main spars).

Very good behaviour of the airframe is demonstrated.

The objective to demonstrate a significant extension of the Mirage 2000 fatigue life (in a "Safe Life" approach, with punctual damage tolerance) is achieved.

4.3. FRENCH CL-415 STRUCTURE INTEGRITY PROGRAM (DGA AERONAUTICAL SYSTEMS)

The French Government civil defence agency (Sécurité Civile - DSC) experienced re-occurring technical incidents and a tragic crash of a CL415 Canadair in 2005. The DGA was asked to a structure integrity program on the CL415 Canadair fleet, similarly as on other military fleets, with two main objectives: flight safety and maintenance optimization in order to guarantee high dispatch reliability during the summer.

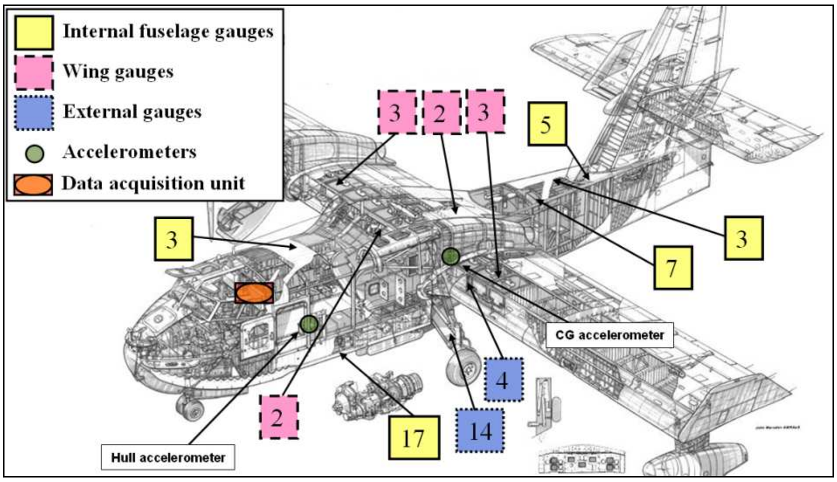
A structure integrity group was created which bring together the users, manufacturer, maintenance maker and airworthiness authorities to collect and share the structural event on the fleet. As a need for motoring arises and the technical basis were insufficient, an in-service measurement action were launched, which put into effect in 2011-2012.

This action was split in five phases:

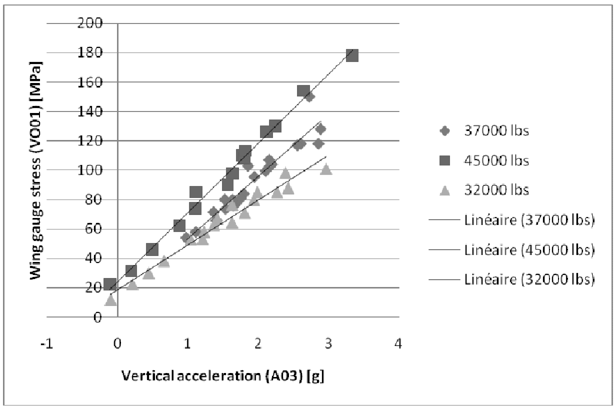
1. A definition of the hot spots based on the analysis and classification of already known damages was led thanks to a collection done over the years by the maintenance contractor. Apart from the usual instrumented points (wings and tail fin spars, landing gear members, fuselage, etc.), other zones were defined by ranking regularly damaged areas (wing to fuselage junction, hull, tail frame, etc.). The result was the definition of a 8 zone of interest with need of more detailed investigations.

2. To build up knowledge, one Canadair was fully equipped with sensors, wiring and data acquisition unit. Flight safety must be guaranteed during the OLM period. The equipment has been proven compliant with this selection of safety rules :

- No interference with the use of the a/c during fire extinction operations,
- Mechanical resistance of the equipment and fasteners,
- Electric and electromagnetic compatibility,
- Absence of additional risk due to fire, lightning, …
- No corruption of navigation data,
- Update of documentation if needed for pilots, operation and maintenance crew

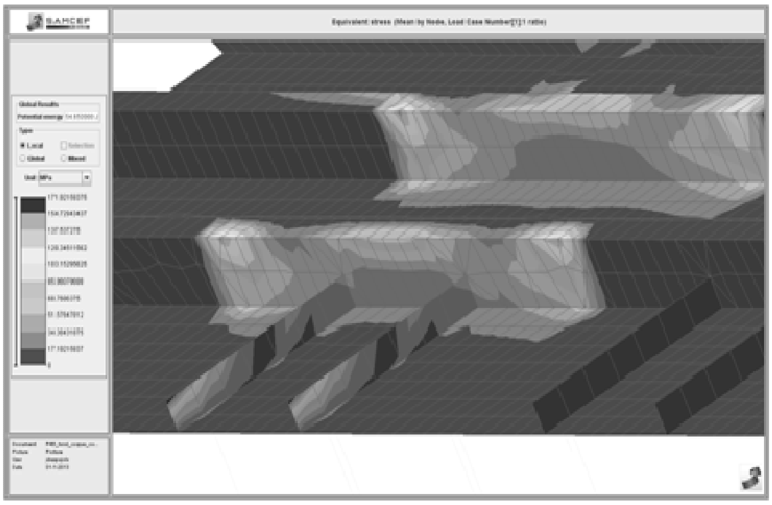


3. A specific flight test campaign with calibrated manoeuvres was performed. The idea was to make a first correlation between flight parameters independently with local stresses. It enables the definition of the transfer functions linking the local stresses with the aircraft attitude or manoeuvre. In the case of the Canadair, manoeuvres can be quite uncommon: offshore or on lakes scooping, high and concentrated gust speeds, severe pull-outs.



4. An in-service measurement period started in July 2012, during the "fire" summer season when the aircraft is used by the DSC. The objective is to collect data with representative conditions (various crews, flight conditions, swell status, missions …). The monitoring during real operational missions should also help the DGA to

find the most severe loading conditions by zones, to understand particular phenomena and improve the knowledge of structural behaviour. As an example, few strong strains observed on the hulls should be observed during OLM as they often happen in "normal" conditions as classified by pilots. When needed, a FEM analysis were conducted to understand the zone behaviour.

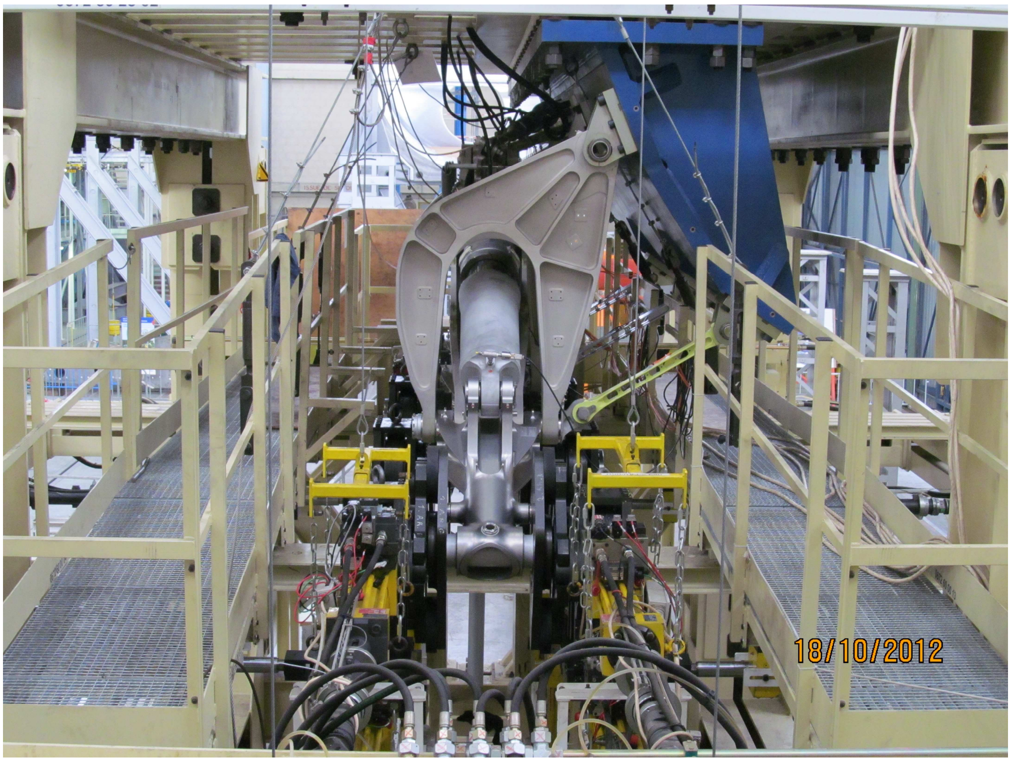


5. Structure analysis and creation of severity and fatigue index, depending of the zones to classify the flight spectra into structural severity. A loading data base is also created to easy to understand and to help to solve the classical technical event. The possibility to generalize the index on other aircraft of the fleet only equipped with accelerometer is investigated.

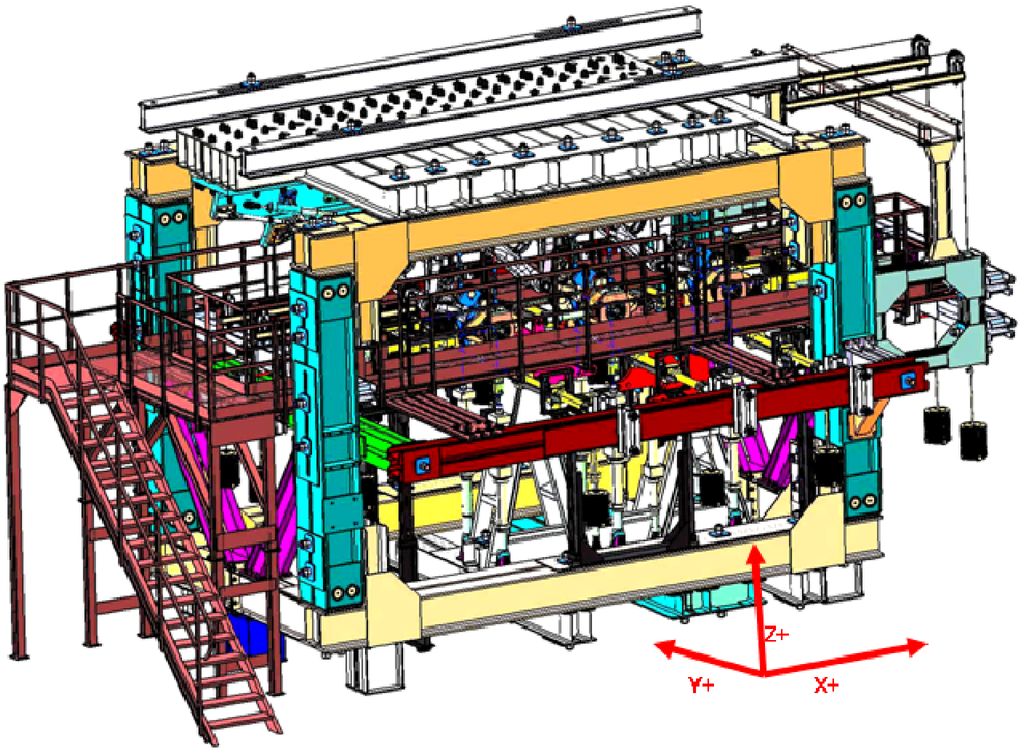
As a result, a good participation of the aircraft crews is experienced. Some interesting data were also obtained to understand the criticity of the loading sequences. The measurements are still on-going and the relationship with the flight parameters are still to be investigated.

4.4. A400M MAIN LANDING GEAR FATIGUE TEST (MESSIER BUGATTI DOWTY AND DGA AERONAUTICAL SYSTEMS)

DGA TA is currently performing the A400M Main Landing Gear Fatigue Test on a specimen representative of the series production.



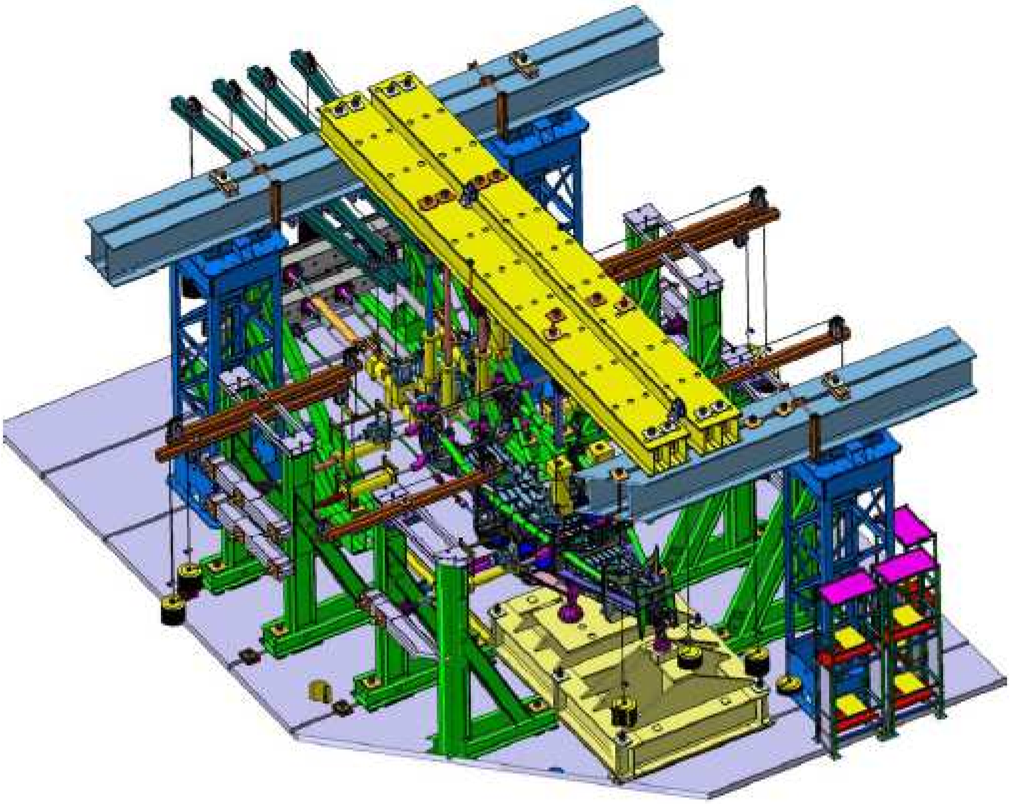
The aim is to simulate 50,000 cycles (SF) to validate 10,000 Flight Cycles (FC) which is the design goal. Load spectrum includes the application of combination of flights grouped in blocks of 200 flights. Load spectrum at the end is in line with the typical aircraft usage (mission mix) defined by a breakdown between four basic missions. Typical ground loads, kneeling actuator loads and extraction retraction loads are simulated.



The loading is achieved using twenty four independent load channels (eight per leg), each fitted with spherical bearings at both ends. All load transducers are located as near as possible of the load introduction point to have a load value recorded by the transducer very close to the real load introduced into the specimen.

4.5. A400M PYLON FATIGUE TEST (AIRBUS AND DGA AERONAUTICAL SYSTEMS)

In the frame of A400M certification, DGA TA is performing the fatigue test of the A400M pylon. This fatigue test re-uses a test rig which was the one developed and used for the A400 pylon static test. The test installation includes 16 hydraulic jacks. Specimen behaviour is followed by 26 displacement transducers and by a maximum of 450 strain gages.



Design goal is 10,000 Flight Cycles with a scatter factor of 3, leading to simulate 30,000 cycles (SF). Load spectrum includes blocks of flights built on 120 different loading cases.

The test programme is divided into several phases including a fatigue phase of 2 DSG, a damage tolerance phase of 1 DSG, a fail-safe phase (of 5 inspection intervals duration) and residual static tests.

PAGE WITHOUT TEXT