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AGEING AIRCRAFT RESEARCH IN THE NETHERLANDS

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1. INTRODUCTION

The problems of Ageing Aircraft are worldwide. Hence, actions to overcome or prevent these problems should be taken in international collaboration.
The Federal Aviation Administration FAA and the Netherlands Civil Aviation Department RLD have signed a Memorandum of Cooperation in the area of structural integrity, with specific reference to research on problems in the area of Ageing Aircraft.
This paper gives an overview of the Research currently carried out on this subject in the Netherlands. The work described is largely done at the National Aerospace Laboratory NLR. The major part is done under contracts with RLD and the FAA, as part of forementioned cooperation agreement.

2. GENERAL CONSIDERATIONS

Early in 1991, a special Working Group of GARTEUR (Group on Aerospace Research and Technology in Europe) met in the Netherlands to review and discuss the A/A (Ageing Aircraft) problem and potential Research on the subject to be done by the respective research institutes in Europe.
In their overview, the group concluded that the "Multiple Site Damage" problem is the main issue in the Aging Aircraft problem. This MSD-problem is of particular importance for, but not restricted to, lapjoints in pressurized fuselages.
Further the group concluded that distinction should be made between the acute A/A-problems in the current fleet of (aged) aircraft on the one hand and the aspect of preventing A/A-problems in future aircraft on the other.
With regard to the first category, considerable efforts have been made during the past few years. Task Groups, involving both the industry and the operators reviewed the various aircraft types. Supplemental Inspection Programs were specified and "terminating actions" were defined.
Broadly speaking, it appears that the A/A-problem for the existing fleet is under control.

Hence it was concluded that the research effort of the Institutes should concentrate on the second category, that is the prevention of A/A-problems in future aircraft. Potential research areas were considered to be:

- Improved structural design, e.g.:
  - improved structural joints
  - improved (fracture mechanics) analysis tools
  - use of advanced materials, e.g. mixed laminates
- maintenance/inspection techniques and procedures:
  - NDI techniques development
  - automated inspection techniques
  - periodic overloads of pressure cabins as a means to delay crack initiation and crack growth and, thus, to extend inspection intervals
- Increased knowledge of operational loads and aircraft usage.

These considerations have served as a basis for the current research plan on Ageing Aircraft as carried out in the Netherlands.

3. A/A-RELATED RESEARCH PROJECTS AT NLR

The current research projects related to A/A at NLR can be divided into two main groups, namely:

i. Research related to MSD in fuselage lapjoints.

ii. Research on operational flight loads.

The figures 1 and 2 present the different projects under these headings. The projects will be briefly described in the following sub-chapters.

3.1. Research related to MSD in fuselage joints

3.1.1. Bi-axial tests on realistic fuselage lap joints

A large test program is underway on fuselage lapjoints under bi-axial loading. The majority of joint configurations to be tested will be representative for the Fokker F28 fuselage structure. In addition, USA made specimens will be tested under bi-axial loading, to compare results with those obtained in tests done in the USA under uni-axial loading. Figure 3 summarizes the main test variables. Figure 4 shows the load introduction in the NLR-specimen by means of unidirectional aramid fibre composite slabs that are attached to the specimen by bonding.

The objectives of this rather extensive test programme are:

- to get an improved understanding of the start and development of MSD in realistic riveted joint configurations;
- to determine the effect of bi-axiallity;
- to obtain quantitative information on initiation life and crack growth, including the amount of scatter;
- to check the reliability of the available NDI-techniques for MSD detection.

3.1.2. Analytical modelling of MSD

The susceptibility of a lapjoint to MSD depends on the configuration of that joint. A relatively simple "MSDS-parameter" (Multi Site Damage Sensitivity) has been defined, relating the growth rates of larger and smaller cracks. It is a function of:

- rivet pitch, diameter, and type;
- number of rivet rows and sheet thickness;
- friction;
- applied load.

A first check, using recent FAA test data gave promising results. This MSDS-concept will be further developed.

In addition, a recent computer program to predict MSD, prepared for FAA by FractuREsearch Inc., will be further developed to include other configurations and stress distributions. Available MSD test data will be used to validate the analytical tools.

3.1.3. Statistical data on crack initiation in riveted joints

Scatter is of crucial importance in MSD: If there were little or no scatter in crack initiation life, a uniformly loaded lapjoint showing no cracks at one inspection might show cracks near all rivets at the next inspection!
Unfortunately, systematic data on scatter in riveted joint fatigue life appear scarce. A literature survey of existing data and an analysis of the currently generated test data will be made. If necessary, a test programme on simple riveted joint specimens representative of current fuselage structure will be proposed to generate further statistical information on scatter.

3.1.4. Periodic overloads as a means to improve fatigue performance

Periodic high loads are known to cause residual compressive stresses in notches or at crack tips, retarding crack initiation or crack growth.
A study into the feasibility of periodic overloading (say up to 1.3 p once per 10,000 flights), as part of normal maintenance procedure, to improve the fatigue performance of fuselages is foreseen*.

3.2. Research on operational flight loads

3.2.1. Participation in the FAA flight loads program

As shown earlier in this Conference, FAA has initiated a very ambitious program on aircraft flight loads. The NLR participates in this program through two different tasks, described as:

1. Acquisition, review and publication of existing European sources of flight load data.
2. Rendering advice on load measurement projects, both for transport and commuter aircraft, with regard to the instrumentation, data analysis and data interpretation.

The European flight data acquired so far include:

- Fokker F27/F28 fatigue meter data.
  For many years, at least two aircraft of each operator were equipped with a counting accelerometer. The acquired data, covering millions of flights, provide valuable information about the variation in load experience between different operators in the short haul- and commuter environment. Fig. 5 gives an illustration of the type of information obtained. Note that for larger Δn values the load factor experience per flight may differ by a factor 10 in severity between different operators.
- NLR B747 ACMS load data.
  NLR has built up a very detailed load data base, covering about 100,000 flight hours from B747 ACMS recordings.
- ONERA "rare event" ACMS data base.
  The ONERA (France) has built up a large data base, covering more than one million flights and a variety of aircraft types on load occurrences in which the

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* It must be stressed that the present concept should not be confused with so-called proof testing. In our opinion previous studies have shown that proof testing as a cheap alternative for structural inspection is <u>not</u> a viable concept.

incremental load factor exceeded 0.5 g.

- RAE fatigue meter database.
  Some decades ago, the RAE (UK) set up a load data base from counting accelerometer data in combination with recorded speed and altitude. This data base, covering 30, 000 flights, includes a large amount of information on load experience at relatively low cruise altitudes.

The acquired load data will be re-analysed using a format that is compatible with existing US data sources (e.g. NACA VGH data) according to the so-called Pratt formula. A PSD-based approach recently proposed by Dr. Houbolt (formerly at NASA) will be used also. This method is presented in AGARDograph 317 "Manual on the Flight of Flexible Aircraft in Turbulence".

It will be clear that the analysis procedures chosen for the "old" data should be compatible with the analysis format selected for the "new" data that will be obtained in the planned FAA-data acquisition program.

3.2.2. FOKKER F100 tail load measurements

Flight load statistics available are largely restricted to c.g. acceleration data. Little information on the service load experience of empennage structures is available. Some years ago, the NLR started a project, sponsored by the Netherlands Agency for Aerospace Programs, to measure tail loads on a commercially operated Fokker F100. The instrumentation used consists of a simple 4-channel recorder with solid state memory recording 3 strain gage signals plus lateral acceleration at the tail. Additional information, like c.g. acceleration, speed, altitude, flap position, etc., are derived from the on-board ACMS recorder. Figure 6 shows the instrumentation. Histories of some of the recorded parameters during one flight are depicted in Fig.7. The loading of the stabilizer is presented as"Asymmetric Bending Moment" and "Symmetric Bending Moment". The measurements, which were fully supported by the Fokker company and the operator KLM, were interrupted due to selling of the aircraft but they may be resumed in the future.

3.2.3. Load monitoring system for Nusantara Aircraft Industry

The NLR supports the Indonesian aircraft manufacturer IPTN in the definition, procurement, installation and operation of a load monitoring system to be installed in 3 (operational) CN235 aircraft.
The objectives of this project are:

- Verification of the CN235 Design Fatigue Load spectra.
- Build-up of statistical data on the gust experience in the tropical environment of the Indonesian Archipelago.

The instrumentation consists of a nine-channel data recorder with solid state memory and on-board data reduction (peak/valley detection etc.). The following quantities are recorded:

- bending moments in wing root, vertical tail and horizontal tail;
- c.g. acceleration;
- cabin pressure;
- speed and altitude.

Additional information about flights will be obtained from written forms.

The gust data analysis procedure is compatible with the one to be applied to the FAA flight loads data.

As a next step, it is intended to define a simplified version of the recorder system, which may be used as an "operator oriented" fatigue load monitoring system.

4. SUMMARY AND CONCLUSION

The present paper gives a brief review of current research at NLR related to the problems associated with Ageing Aircraft.

This research is primarily directed towards the prevention of A/A problems in future aircraft and is concentrated on two areas:

- prevention of MSD in lap joints;
- improved knowledge on operational load experience.

The major part of this research is carried out in some form of international cooperation.

The Memorandum of Cooperation between FAA and the Netherlands Civil Aviation Department in the area of aviations safety provides an effective framework for the coordination of research efforts related to A/A problems.

NLR experiences this cooperation with and support from FAA as very stimulating.

Figure 1

RESEARCH ON MSD

- BI-AXIAL TESTS ON REALISTIC FUSELAGE LAP JOINTS
- ANALYTICAL MODELLING OF MULTIPLE SITE DAMAGE
- STATISTICAL DATA ON CRACK INITIATION IN RIVETED JOINTS
- PERIODIC OVERLOADS AS A MEANS TO IMPROVE FATIGUE PERFORMANCE

Figure 2

RESEARCH ON FLIGHT LOADS

- PARTICIPATION IN FAA-FLIGHT LOADS PROGRAM
- SERVICE LOAD MEASUREMENTS ON F100 TAIL STRUCTURE
- ASSISTANCE WITH DEVELOPMENT LOAD MONITORING SYSTEM NUSANTARA AIRCRAFT INDUSTRY

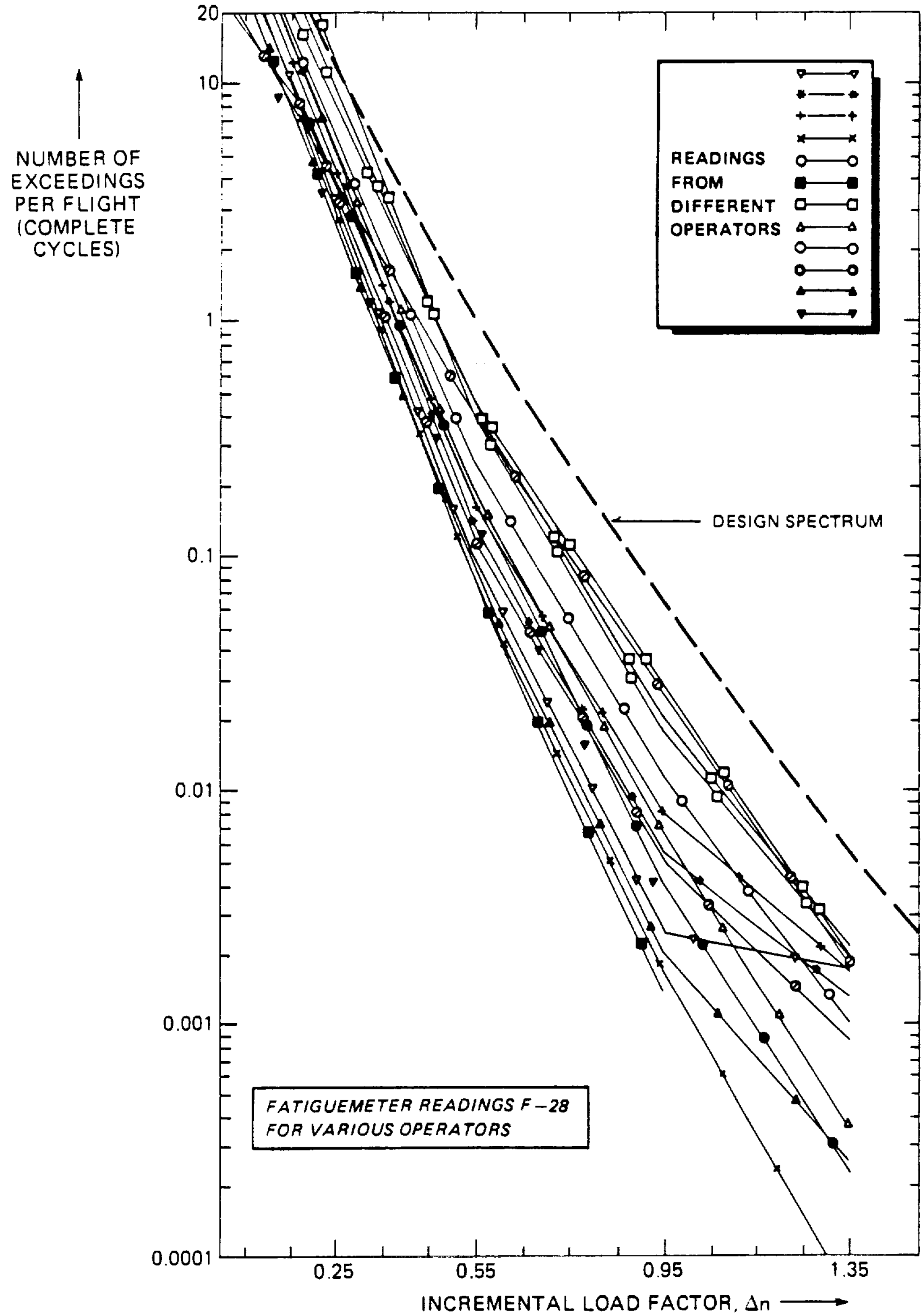
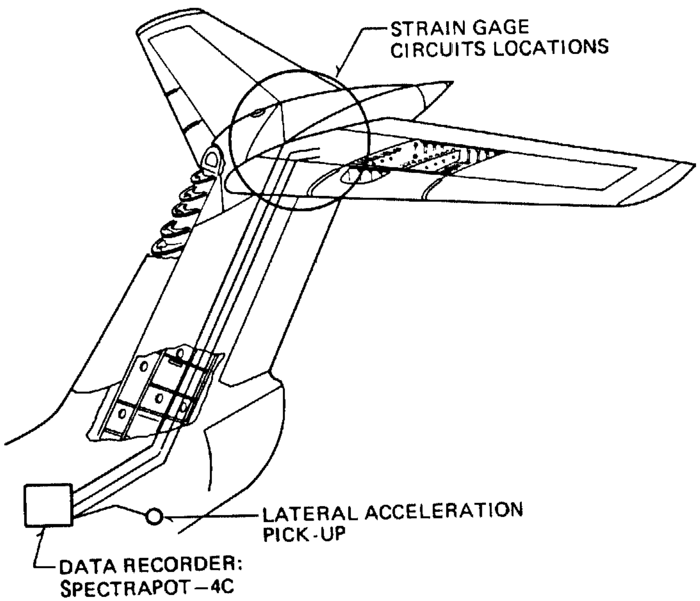


Figure 5 Variation in load factor experience between F-28 operators

Figure 6

REVIEW OF F–100 SERVICE–TAILLOAD MEASUREMENTS



MEASUREMENTS WITH SPECTRAPOT RECORDER:

- LATERAL ACCELERATION OF TAIL

FROM STRAIN GAGE BRIDGES:

- B.M. OF RIGHT STABILIZER
- SYMMETRIC COMPONENT STABILIZER B.M.
- ANTISYMMETRIC COMPONENT STABILIZER B.M.

ADDITIONAL INFO FROM ACMS SYSTEM:

- ADMINISTRATIVE FLIGHT DATA
- C.G. VERTICAL ACCELERATION
- SPEED
- ALTITUDE
- ELEVATOR POSITION

Figure 7

F100 TAIL LOAD MEASUREMENTS

EXAMPLE OF RECORDED PARAMETER HISTORIES

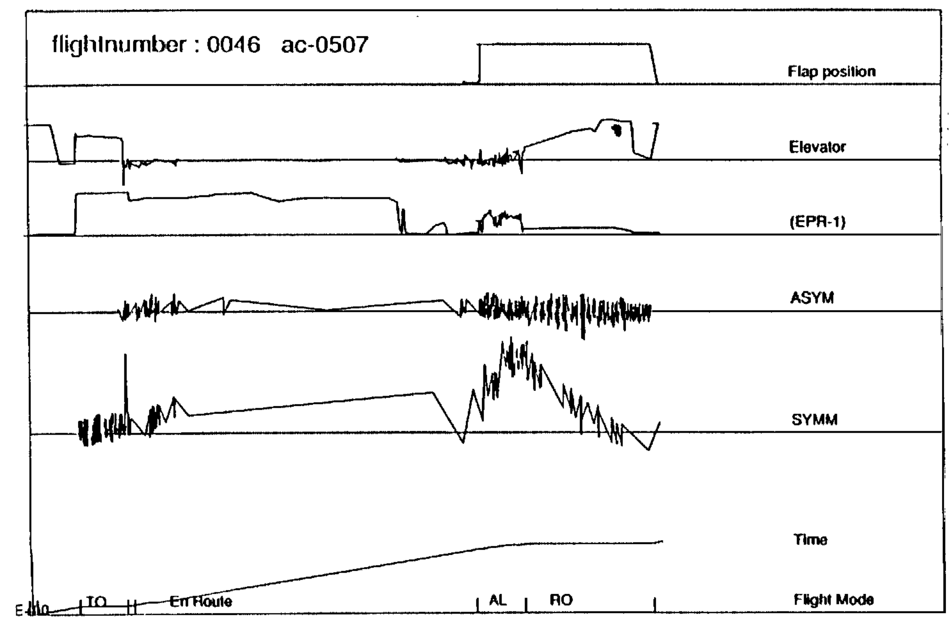


Figure 3

BI-AXIAL TESTS ON LAP JOINTS

SPECIMEN WIDTH 540 mm (21 inch)

SPECIMEN CONFIGURATIONS:

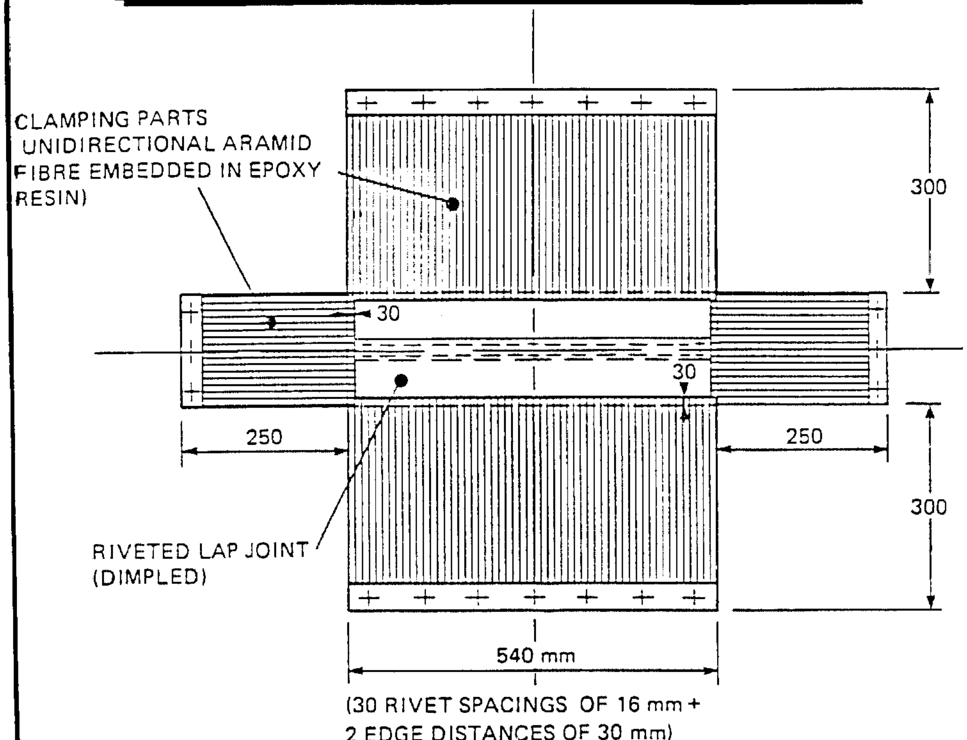
- 2 AND 3 RIVET ROWS
- DIMPLED AND COUNTERSUNK RIVETS
- BONDED AND UNBONDED JOINTS

- LOCAL DE-BONDS

BOTH BI-AXIAL AND UNI-AXIAL
C/A TEST LOADING.

Figure 4

LOAD INTRODUCTION SYSTEM TO BIAXIAL MSD-SPECIMENS



TESTING PROGRAMME:

- C–A TESTING WITH σ_{max} = 85 MPa (BASED ON Δp = 7.45 psi)
- TESTING FREQUENCY 6–10 Hz
- FREQUENT INSPECTIONS (BOTH VISUAL AND WITH MORE ADVANCED NDI EQUIPMENT)