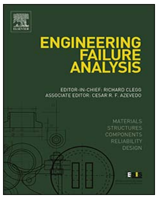
Engineering Failure Analysis 83 (2018) 207–219

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal



Verification of an airframe fatigue life monitoring system using ex-service structure

L. Molent[a,*], V. Mau[b]

[a] DST Group, Aerospace Division, 506 Lorimer Street, Fishermans Bend, Victoria 3207, Australia
[b] Advanced VTOL Technologies, 423W Ballarat West, Victoria 3350, Australia

ARTICLE INFO

Keywords:
AA7050
Fatigue
Crack growth
Fatigue tracking

ABSTRACT

In this paper the verification of the Royal Australian Air Force's (RAAF) F/A-18 Hornet Airframe Service Life Monitoring system is summarised. The availability of a significant number of RAAF ex-service centre fuselage sections with known usage facilitated this effort. Using an enhanced teardown procedure, in-service crack growth was identified at a significant number of locations. By comparing measured in-service growth with full scale fatigue test-demonstrated growth, and fitting failure distributions to the in-service data, the effectiveness of the monitoring system in maintaining a specific probability of failure was assessed.

Abbreviations and notation

AFHRS	AirFrame Hours
ASLMP	Airframe Service Life Monitoring Program
CB	Centre Barrel (wing attachment bulkheads)
CPOF	Cumulative Probability of Failure
DIL	Damage Item Location
DST Group	Defence Science and Technology Group
EOS	End of Service
EPS	Equivalent Pre-crack Size
ETH	Equivalent Test Hours
FINAL	Flaw IdeNtification through the Application of Loads
FALSTAFF	Fighter Aircraft Loading STAndard For Fatigue Evaluation
FLEI	Fatigue Life Expended Index
FSFT	Full Scale Fatigue Test
FT55	IFOSTP certification centre fuselage FSFT
IFOSTP	International Follow-On Structural Test Project
in	inches
IVD	Ion Vapour Deposition
LHS	Left Hand Side
MLG	Main Landing Gear

---

[*] Corresponding author.
E-mail address: Lorrie.Molent@dst.defence.gov.au (L. Molent).

http://dx.doi.org/10.1016/j.engfailanal.2017.09.019
Received 27 July 2017; Received in revised form 19 September 2017; Accepted 29 September 2017

mm	millimetres
MSDRS	Maintenance Signal and Data Recording System
MSMP2	Mission Severity Monitoring Program Version 2
NDI	Non-Destructive Inspection
NSD	Notice of Structural Deficiency
POF	Probability of Failure
QF	Quantitative Fractography
RAAF	Royal Australian Air Force
RCAF	Royal Canadian Air Force
RHS	Right Hand Side
RST	Residual Strength Test
SAFE	Structural Appraisal of Fatigue Effects
SLL	Safe Life Limit
USN	United States Navy
WRBM	Wing Root Bending Moment
Y	Y axis of the global aircraft co-ordinate system
Z	Z axis of the global aircraft co-ordinate system

1. Introduction

Fatigue monitoring of airframes has developed to the stage where it is now incumbent for all fighter and many other types of aircraft to incorporate a fatigue monitoring system. These systems typically collect operational data for the calculation of the airframe's safe-life or crack inspection intervals relative to a reference spectrum. Many of these systems are complex, incorporating such features as data integrity checking, strain gauge calibration algorithms and damage calculation algorithms. Whilst it may be possible to validate the robustness and accuracy of specific system components (e.g. the damage algorithm can be tested against fatigue coupon results [1]) the verification of the performance (i.e. fit-for-purpose) of the in-service system as a whole presents a much bigger challenge.

This paper summarises the verification assessment of the Royal Australian Air Force's (RAAF) F/A-18 Hornet individual Airframe Service Life Monitoring Program (ASLMP – known as MSMP2 R1.8) (for more details see [2,3,4]). The ASLMP was designed [2] to ensure compliance with the requirements of the RAAF aircraft's reference structural design certification standard, namely UK Defence Standard 970 [5] (referred to as “Def Stan” herein) principally to help maintain an acceptable cumulative probability of failure (CPOF) limit (for other ASLMP functions see [7,8]). The availability of a significant number of ex-service centre fuselage sections (referred to as centre barrels – CBs) with known usage has facilitated this effort. The fatigue usage of these components was specified as Fatigue Life Expended Index (FLEI) for each aircraft and is a major output from the ASLMP. Using an enhanced teardown procedure, in-service cracking was identified at a significant number of locations. The in-service cracking corresponded to the same locations found cracked in the full-scale fatigue life certification test article used to calibrate the usage monitoring system. By comparing the measured in-service growth with the full-scale test-demonstrated growth subjected to the reference spectrum, and by estimating the CPOF by considering the variability in the derived crack growth lives, the performance (i.e. fit for purpose) of the monitoring system was assessed. This process checked if the CPOF at the promulgated safe-life limits (SLL) of the locations considered were below the acceptable threshold, which consistent with [5], was one-in-a-thousand.[1] For this comparison, the detected in-service crack growth was measured using quantitative fractography (QF) and a simple but reliable model of this growth [9] was applied to produce a prediction of its future growth had it been left in-service.

This paper provides a brief description of the ASLMP, the CB structure, methodology used to extract crack growth curves from the ex-service CBs and a summary of the results.

2. The RAAF F/A-18 Hornet Airframe Service Life Monitoring Program

2.1. Mission Severity Monitoring Program Version 2

The Hornet ASLMP consists of many elements and the most relevant here are briefly described. The damage algorithm/program is known as the Mission Severity Monitoring Program Version 2 (MSMP2) and uses a fixed 35 × 35 level unit damage matrix (see [6] for details). MSMP2 calculates the cumulative FLEI on a per flight basis for RAAF F/A-18 aircraft from peak-valley counts from a strain gauge chosen to respond principally to wing root bending moment (WRBM). The FLEI is an estimate of the proportion of the originally certified fatigue life of the aircraft which has been expended to date, i.e. a FLEI of 1.0 normally indicates that an aircraft has accumulated fatigue damage equivalent to the maximum acceptable safe level demonstrated by the certification fatigue testing and analysis. The MSMP2 damage algorithm was validated by comparing predicted lives with fatigue coupon test results [1], where it was shown that the correct spectra severity ranking was achieved.

---

[1] Def Stan assumes two critical locations mirrored about the centreline of the airframe [5].