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Ageing Aircraft: Corrosion and widespread fatigue - AMC 20-20

A presentation given by Dr S. Waite, EASA Structures Expert in Namibia, September 2014

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AIRBUS

Technology Evolution – Impact on Airworthiness
11-12 November, Abidjan, Cote d'Ivoire

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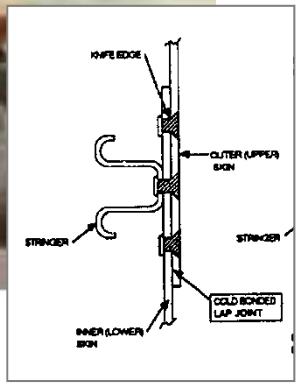
Ageing Aircraft -
Corrosion and Widespread Fatigue Damage:

- Design Certification Perspective (CS25.571, 25.1529)
- NPA 2013/07 'Ageing Aircraft Structures'
  (RMT.0225 (MDM.028(a)) — 23/04/2013)
- AMC 20-20 'Continuing Structural Integrity Programme'
  (current issue (2007) - Corrosion and Widespread Fatigue aspects)

Note:
evolving intent…
meeting this week
in Koeln

Ageing Aircraft – CPCP and WFD

Examples: Aloha… attributed in part to the age of the aircraft and the combination of fatigue and corrosion effects (Multiple Site Damage (MSD))



(missed cold bond lap joint disbond inspection SB 737-53A1039)

Ageing Aircraft – CPCP and WFD

Examples: C130 'water bomber'… attributed in part to the age of the aircraft and change of use (fatigue mission/inadequate DT inspection)

'operator devised a maintenance and inspection program based on the specified USAF maintenance technical order but did not develop a depot level inspection requirement to ensure continued long-term airworthiness and damage tolerance that would account for the stresses on the airplane resulting from its new firefighting role and the increasing age of the airplanes', ref NTSB file LAX02GA201 File No. 14459 06/17/2002

Ageing Aircraft – CPCP and WFD

Examples: includes consideration of repairs:

(cold bond belly skin repair – corrosion/cracking along outer fastener row + pillowing)

Ageing Aircraft – CPCP and WFD

Ageing Aircraft:

– the relevant design Certification Specifications (CSs):

Ageing Aircraft
Corrosion and Widespread Fatigue Damage:
Design Certification Perspective

CS25.571: ***Damage-tolerance & fatigue evaluation of structure***

'(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, or accidental damage, will be avoided throughout the operational life of the aeroplane'

Environmental Damage - ED

Ageing Aircraft – CPCP and WFD

CS 25.571: Damage Tolerance and Fatigue Evaluation of Structure:

'(3)…..inspections or other procedures must be established as necessary to prevent catastrophic failure, and must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529'

CS 25.1529: Instructions for Continued Airworthiness:

'Instructions for Continued Airworthiness in accordance with Appendix H must be prepared'

Ageing Aircraft – CPCP and WFD

CS 25 Appendix H: Instructions for Continued Airworthiness must include….

H25.1 General (b) : ……..information essential to CAW of the aeroplane.

H25.3 Content: includes….

(b)(1) Maintenance Instructions: …..an inspection programme……

(d) … details of NDT methods…

H25.4 Airworthiness Limitations Section: …manuals must include separate mandatory section including replacement times, structural inspection intervals…under CS 25.571.

Ageing Aircraft – CPCP and WFD

NPA 2013-07

Notice of Proposed Amendment 2013-07
(task in progress – amendment date TBD)

Ageing Aircraft Structures
RMT.0225 (MDM.028(a)) — 23/04/2013

- proposes changes to the Implementing Rules, certification standards, Acceptable Means of Compliance and Guidance Material in order to ensure that the safety risks associated with the 'ageing aircraft' issues are mitigated

Ageing Aircraft – CPCP and WFD

NPA 2013-07

… age of an aircraft depends on factors including chronological age, number of flight cycles, and number of flight hours

…individual aircraft components age differently, and some of the ageing mechanisms are fatigue through repetitive cycles, wear, deterioration and corrosion.

…since these factors will increase the pace and effects of the ageing process, they can be a significant safety concern if not properly understood and managed throughout the life of the aircraft.

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposes following changes:

(a) amend Part-21 ‘Certification of aircraft and related products, parts and appliances, and of design and production organisations’;

(b) amend Part-26 ‘Additional airworthiness requirements for operations’ and the corresponding Certification Specification CS-26’;

(c) amend CS-25 Certification Specifications and the corresponding AMC for large aeroplanes';

(d) amend AMC 20-20 'Continuing Structural Integrity Programme';

(e) amend AMC to Part-M 'Continuing Airworthiness Requirements'.

This presentation addresses CPCP and WFD aspects of the current version of AMC 20-20

Ageing Aircraft – CPCP and WFD

Ageing Aircraft Programme – History:

- June 1988, FAA conference on ageing aircraft.
- August 1988 aircraft task force established (subgroup of the FAA's Research, Engineering, and Development Advisory Committee), representing the interests of the aircraft operators, aircraft manufacturers, regulatory authorities, and other aviation representatives.
- Airworthiness Assurance Task Force (AATF), now Airworthiness Assurance Working Group (AAWG) of the Aviation Rulemaking Advisory Committee (ARAC),set forth five major elements of a programme for keeping ageing fleet safe.
- Applicability 11 pre-Damage Tolerance CS25 aircraft

Ageing Aircraft – CPCP and WFD

Ageing Aircraft Programme –:

(a) select service bulletins describing modifications and inspections necessary to maintain structural integrity;

(b) develop inspection and prevention programmes to address corrosion;

(c) develop generic structural maintenance programme guidelines for ageing aeroplanes;

(d) review and update the Supplemental Structural Inspection Documents (SSID) which describe inspection programmes to detect fatigue cracking; and

(e) assess damage tolerance of structural repairs.

+ recognised that an additional factor in the Aloha Airlines accident was WFD.

Ageing Aircraft – CPCP and WFD

AMC 20-20 'Continuing Structural Integrity Programme'

current issue (26/12/2007)

Purpose:

- guidance to Type-Certificate Holders (TCHs), STC holders, repair approval holders, maintenance organisations, operators and competent authorities in developing a continuing structural integrity programme to ensure safe operation of ageing aircraft throughout their operational life, including provision to preclude Widespread Fatigue Damage
- aimed at large aeroplanes operated in Commercial Air Transport or are maintained under Part-M…also applicable to other aircraft types *(final scope TBD).*

Ageing Aircraft – CPCP and WFD

Purpose:

- …guidance to supplement the engineering and operational judgement that must form the basis of any compliance findings relative to continuing structural integrity programmes
- …describes an acceptable means, but not the only means, for showing compliance with the requirements... derived from extensive industry experience in determining compliance with the relevant requirements

Ageing Aircraft – CPCP and WFD

Purpose:

Accordingly, the inspection and evaluation programmes outlined in this AMC are intended to provide:

- a continuing structural integrity assessment by each type-certificate holder, and

- the incorporation of the results of each assessment into the maintenance programme of each operator.

Ageing Aircraft – CPCP and WFD

AMC 20-20:

– Corrosion Prevention and Control Programme (CPCP)

Corrosion:

- usually in the form of an electrochemical oxidation of the metal alloy.
- more prevalent in marine environments due to high humidity and exposure to salt.
- weakens the material (reduced cross section and creating stress concentration).
- slow down the corrosion by careful material selection, surface coatings, effective drainage etc

Corrosion combined with fatigue is of greatest concern

CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

- systematic approach to prevent and control corrosion in Primary Structure
- limit the deterioration to a level necessary to maintain airworthiness and restore the corrosion protection
- consists of basic corrosion inspection tasks, task areas, defined corrosion levels, and compliance times
  (implementation thresholds and repeat intervals)

CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

- notify competent authority and TCH of Level 2 and Level 3 corrosion and the actions taken to reduce future findings to Level 1 or better…

Level 1 corrosion:

(1) …occurring between successive corrosion inspections, is local, and can be reworked/blended within allowable limits; or

(2) …local and exceeds the allowable limit, but can be attributed to untypical usage (e.g. mercury spill); or

(3) …light corrosion between successive corrosion inspections tasks; and the latest corrosion task results rework that exceeds the allowable limit.

CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

Level 2 corrosion - between successive corrosion inspections:

(1) …requires single rework/blend which exceeds allowable limit. OR,

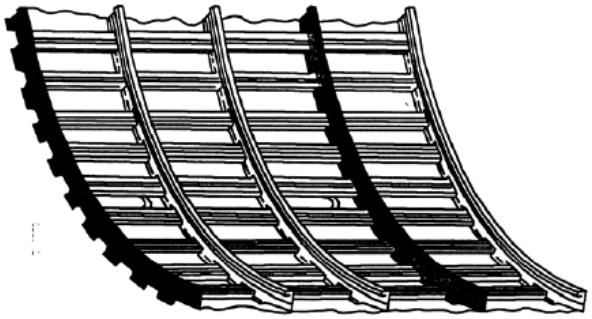
(2)…is widespread and requires a single blend-out approaching allowable rework limits. i.e. not per Level 1 definition

Note:

- *Level 2 corrosion* requires repair, reinforcement, or complete or partial replacement of the applicable structure.

- an effective CPCP controls (prevents/limits) corrosion. Needing to rework damages does not define an effective CPCP.

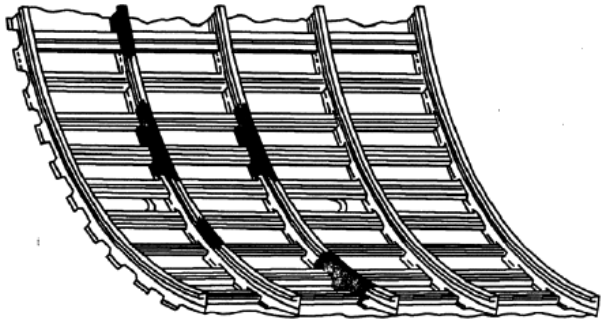
CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)



LOCAL CORROSION

(Corrosion occurring in non-adjacent frames)

Example: local corrosion



WIDESPREAD CORROSION

(Corrosion occurring in adjacent frames)

Example: widespread corrosion

(corrosion on adjacent frames)

CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

Level 3 corrosion:

(1) …occurring during the first or subsequent accomplishments of a corrosion inspection task that the operator determines to be an urgent airworthiness concern.

Note:

- *Level 3* corrosion should be reported to TCH (Type Certificate Holder) and agency
- final level determined by TCH and/or agency

Ageing Aircraft – CPCP and WFD

CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

TCH* to provide (via Baseline Programme manual) :

(1) programme defining frequency and extent of inspections
(2) instructions addressing
- access, lighting, cleanliness, necessary for inspections
- corrosion removal (including allowable limits)
- reapplication of protection systems etc

TCH (for aircraft with ALS (Airworthiness Limitations Section)) to provide statement in ALS to indicate that (iaw intent of CS25.571 and practice of MSG3):

'all corrosion should be maintained to level 1 or better'.

TCH is responsible for monitoring effectiveness of programme and proposing/reviewing changes (via Part M)

* operator(s) may develop CPCP if none provided by TCH (icw competent authority approval)

need for SMS approach!

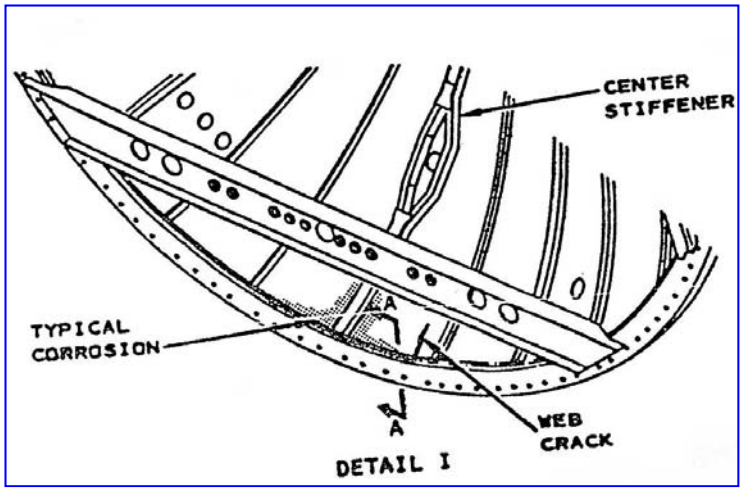
CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

Corrosion Example: Airworthiness Directive corrosion inspection signed off in March (nil finding), corrosion found August (same year!)

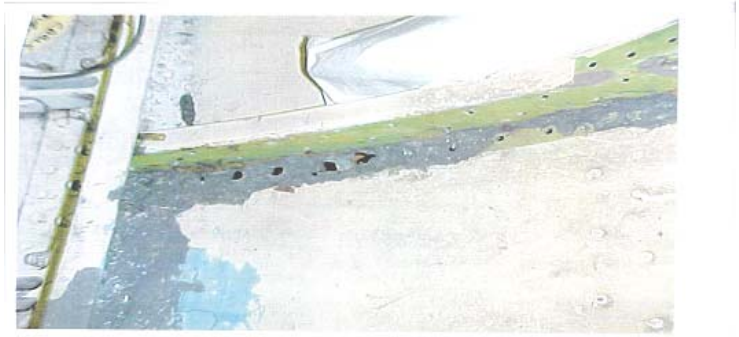
- appropriate access necessary (RPB under toilet installation)
- appropriate time for task (implied CPCP level inspection required (access, lighting etc), March sign-off following overnight ramp check!)

- operator needs to understand purpose

- TCH needs to understand what is achievable



14in. corrosion + crack in Rear Pressure Bulkhead (RPB)



CORROSION PREVENTION AND CONTROL PROGRAMME (CPCP)

Further points (requiring co-ordination with competent authority):

- findings made outside scheduled CPCP inspections indicate an ineffective programme, requiring appropriate revision
- removal of aircraft from storage
- adding aircraft to the fleet
  - aircraft previously operating under a maintenance programme: initially use most conservative of previous and current fleet CPCP schedules
  - aircraft not previously operating under a maintenance programme: complete initial CPCP task before operation
- change of use, e.g. operating environment

Ageing Aircraft – CPCP and WFD

AMC 20-20:

– Widespread Fatigue Damage (WFD)

Ageing Aircraft – CPCP and WFD

Widespread Fatigue Damage (WFD):

- characterised by cracks originating at multiple locations of sufficient size and density that the structure no longer maintains its required residual strength
- crack interaction
- damage tolerance analysis from a single or dual crack origins is not sufficient to preclude WFD
- separate WFD assessment and determination of specific maintenance actions is necessary
- operation should not be allowed beyond a certain point in the life of the airframe, known as the Limit of Validity (LoV) of the structural maintenance programme.

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

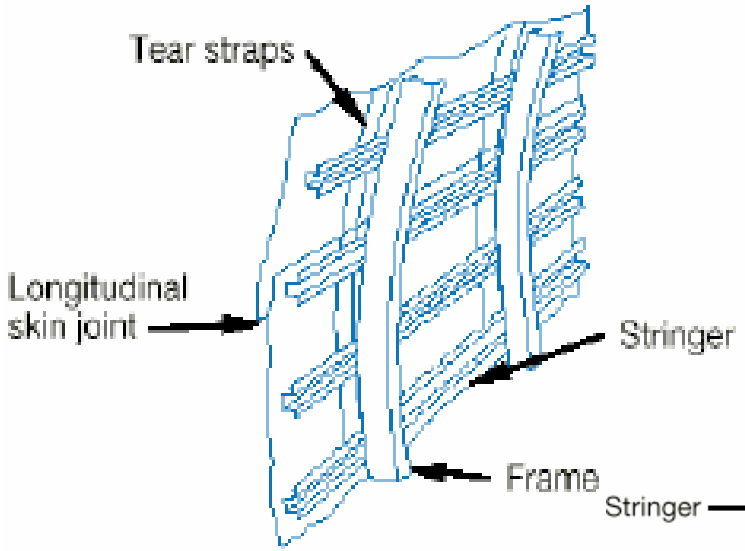
- Structures typically:
  - degrade with use
  - have an LoV (i.e. limited validation based upon fatigue test evidence)
  - significance to safety of use beyond LoV unknown
  - only limited local damage expected before Design Service Goal (DSG)
- evidence suggests
  - some structures experience of multiple damage

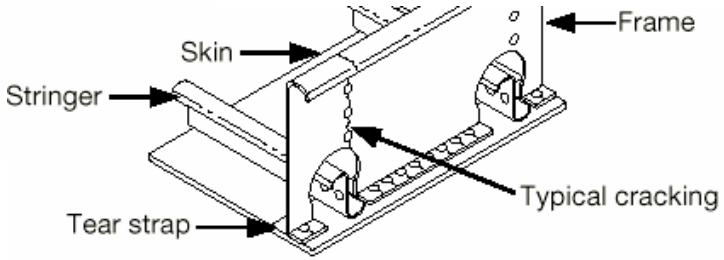
    (Multi Element Damage (MED), Multi Site Damage (MSD))
  - crack interaction (invalidates predictions and large damage capability (LDC))
  - may not be addressed by existing inspection programmes,

    e.g. Supplementary Structural Inspection programme (SSIP), as required by Part M, intended to find all types of fatigue

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

- Multiple Element Damage (MED): A source of widespread fatigue damage characterised by the simultaneous presence of fatigue cracks in similar adjacent elements:



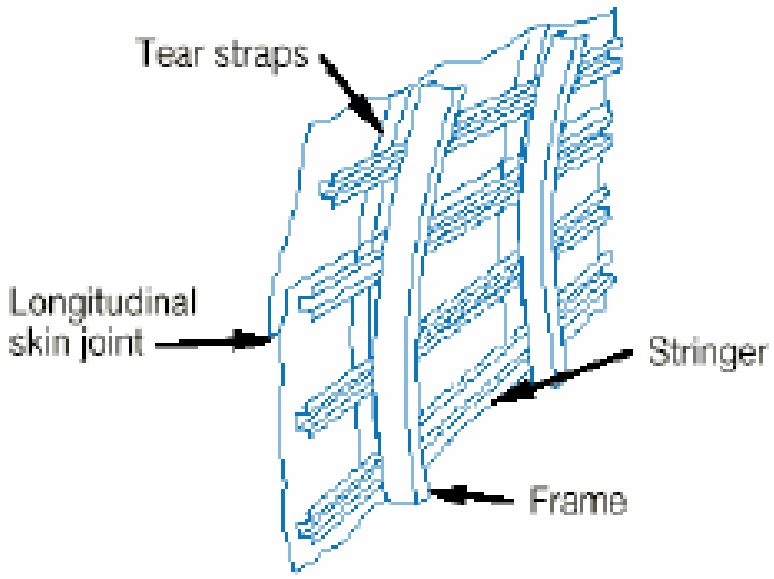


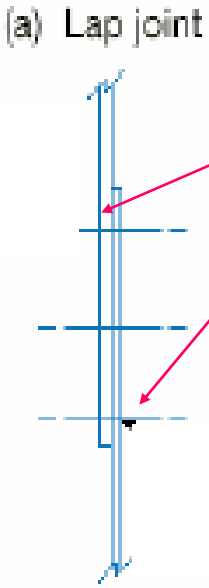
Example: MED

- frames: at stress concentrations, e.g. stringer cut-out at successive longitudinal locations
- tear straps: critical fastener row in skin at tear strap joint

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

- Multiple Site Damage (MSD): A source of widespread fatigue damage characterised by the simultaneous presence of fatigue cracks in the same structural element (i.e. fatigue cracks may coalesce with or without other damage leading to a loss of required residual strength):

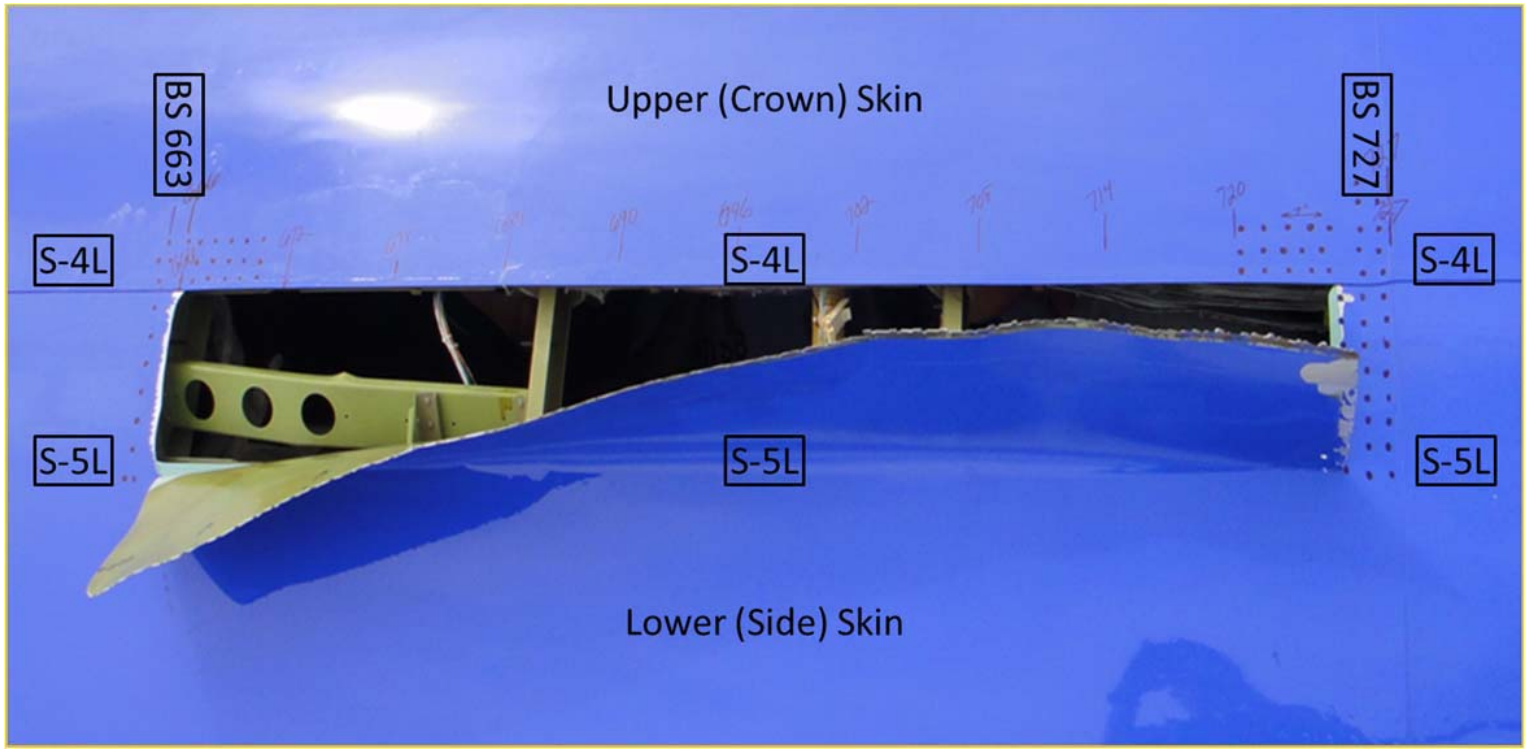




Example: MSD

- lap joints (outer skin upper rivet row, inner skin lower rivet row)
- butt joints (skin outer rivet row, doubler inner rivet row)
- lap joints with inner radius (inner radius)

Ageing Aircraft – CPCP and WFD



NTSB/AAB-13/02 … probable cause of this accident was the improper installation of the fuselage crown skin panel at the S-4L lap joint during the manufacturing process, which resulted in multiple site damage fatigue cracking and eventual failure of the lower skin panel… (38k cycles)

Ageing Aircraft – CPCP and WFD

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

TCH to:

- perform WFD evaluation icw operators
- evaluation has 3 objectives:
  - identify Primary Structure susceptible to MSD/MED
  - predict when it is likely to occur
    - review full scale test data, in-service statistics, teardown, fractographic data
    - identify likely crack initiation, growth, and failure scenarios (model accordingly)
    - consider potential for Discrete Source Damage (DSD)
    - determine Inspection Start Point (ISP), Structural Modification Point (SMP), inspection interval and methods
  - establish additional maintenance actions, as necessary, to ensure continued safe operation of the aircraft

Ageing Aircraft – CPCP and WFD

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

TCH to:

- develop maintenance programme to prevent WFD
(+ agency review/approval of engineering and maintenance actions)
- actions to be incorporated in maintenance programme iaw Part M
- Service Bulletins (SBs) and other service instructions to be reviewed/amended accordingly
- if WFD not provided in necessary timescales, agency may impose life, inspection, and/or operational limitations

LIMIT of VALIDITY (LoV) OF MAINTENANCE PROGRAMME AND EVALUATION OF WIDESPREAD FATGUE)

Revision to WFD evaluation, including LoV:

- new experiences may require amendment to the programme, including LoV (subject to agency review)
- in order to operate an individual aircraft to a revised LoV, all modified and repaired structure should be reviewed
- revised LoV should be entered in the ALS (create ALS, as necessary), clearly identifying inspections and modifications which make this acceptable

Ageing Aircraft – CPCP and WFD

AGEING AIRCRAFT PROGRAMME - IMPLEMENTATION

- iaw Part M, operators must amend the maintenance schedule

- LoV = DSG in the absence of further information

- incorporate within 1yr of TCH making programme available

- fully implement across fleet all beyond threshold maintenance tasks within 4yrs of programme approval by competent authority

- in the absence of further information, modifications and repairs are assumed to be the same age as the airframe

- excludes 'safe life' items
(although life may require review following a change in use)

AGEING AIRCRAFT PROGRAMME - IMPLEMENTATION

Programme	Affected Structure*	Implementation
CPCP	All Primary Structure	½ DSG
SSID	PSEs as defined in CS25.571	½ DSG
SB-Review	SBs that address a potentially unsafe structural condition	¾ DSG
REGs and RAPs	Repairs to fatigue critical structure (FCS).	¾ DSG
WFD	Prmary structure susceptible to WFD	1 DSG

NPA 2013-07* proposed amendments - CS25 & AMC 20-20

(CPCP and WFD aspects)

* see NPA 2013-07 documents for complete details, including proposed CPCP and WFD addendum: http://easa.europa.eu/system/files/dfu/NPA%202013-07.pdf

Ageing Aircraft – CPCP and WFD

NPA 2013-07

Proposed amendments include…

Purpose:

- supports compliance with the latest Part-26 regulations for ageing aircraft structural integrity (Ref. Part 26.300 through 26.370) including Limits of Validity (LoV), WFD evaluation, Damage Tolerance for Repairs and Modifications and structural continued airworthiness programmes.

- requires approved damage tolerance-based inspections are obtained and implemented on all repairs and modifications on aircraft certified for 30 pax or more or for 7 500 lbs

- supports inclusion of ageing aircraft structures programmes in the AMC Part-M (M.A.302).

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

- strengthens links to applicable residual strength requirements (e.g. JAR 25.571 (b), CS 25.571(b))
- significant changes to AMC 25.571

Way of Working:

- strengthens need to review service data on regular basis

CPCP aspects: minor changes

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD aspects: - clarifies initial evaluation expectations/process details

- strengthens link to CS25.571: e.g. adds reminder

'*It should be noted that the majority of aircraft in the European fleet are now damage tolerance certified and that the JAR and CS damage tolerance requirements have always required consideration of all forms of fatigue damage.*'

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues…

'JAR 25.571 at Change 7 (already!) stated:

'(b) Damage tolerance (fail-safe) evaluation.

The evaluation must include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. The determination must be by analysis supported by test evidence and (if available) service experience. Damage at multiple sites due to prior fatigue exposure must be included where the design is such that this type of damage can be expected to occur.'

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues…

'AMC 25.571(a), (b) and (e) stated in Section 2.1.1.:

d. Provisions to limit the probability of concurrent multiple damage, particularly after long service, which could conceivably contribute to a common fracture path.

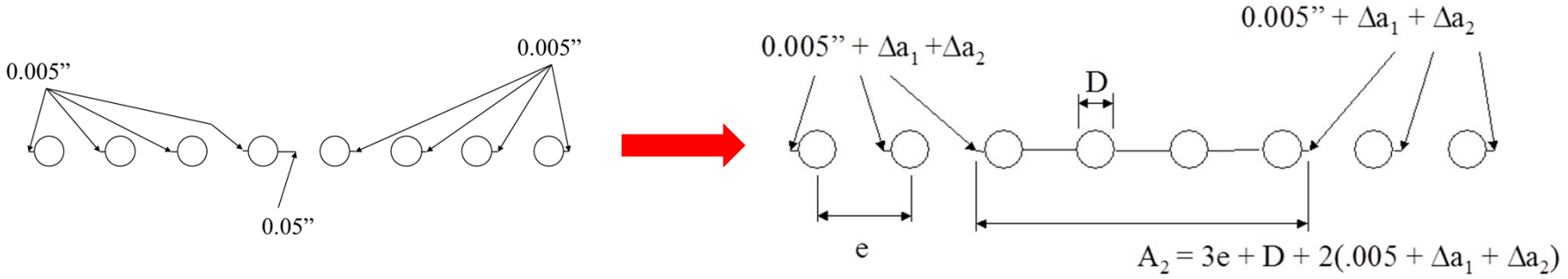
…this would be facilitated by ensuring sufficient life to crack initiation.

Examples of such multiple damage are –

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues…

i. A number of small cracks which might coalesce to form a single long crack;



Example: cracks joining in fastener row*

* R. Eastin, DER Seminar 8th June 2008

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues…

ii. Failures, or partial failures, in adjacent areas, due to the redistribution of loading following a failure of a single element; and

iii. Simultaneous failure, or partial failure, of multiple load path discrete elements, working at similar stress levels.

In practice it may not be possible to guard against the effects of multiple damage and failsafe substantiation may be valid only up to a particular life which would preclude multiple damage.'

Nonetheless, it is not clear, even for later aircraft, that all applicants followed this guidance, hence the development of the EASA ageing aircraft requirements.

Ageing Aircraft – CPCP and WFD

NPA 2013-07

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues suggesting scope…

'- Part 26.300(d) requires TCHs of large transport aeroplanes of MTOM greater than 34 019 kg (75 000 lbs) to establish actions upon which the LoV is dependent.'

Adds note regarding removable parts:

'Note: The LoV applies to aeroplanes, not to individual parts. Should there be any concerns about the service life of a removable component containing Fatigue Critical Structure (FCS) or PSEs, an ALS limitation or SMP* can be mandated on that specific component, which would then need to be tracked'

* **Structural Modification Point (SMP)** is a point reduced from the WFD average behaviour (i.e., lower bound), so that operation up to that point provides equivalent protection to that of a two-lifetime fatigue test. No aircraft should be operated beyond the SMP without modification or part replacement.

NPA proposed Amendments to AMC 20-20 (CPCP, WFD aspects):

WFD: continues…

Adds note regarding repairs:

'For practical purposes it is suggested that the SRM is also reviewed and updated to facilitate its continued applicability up to the extended LoV. If this is not done, all SRM-based repairs will require individual approval.'

Ageing Aircraft – CPCP and WFD

Questions?