AMC 25.562 Emergency landing dynamic conditions

ED Decision 2020/024/R

FAA Advisory Circular (AC) 25.562-1B Change 1, *Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes*, dated 30.9.2015, and FAA AC 20-146A, *Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft*, dated 29.6.2018, are accepted by the Agency as providing acceptable means of compliance with CS 25.562.

[Amdt 25/17]
[Amdt 25/26]

CS 25.563 Structural ditching provisions

ED Decision 2003/2/RM

Structural strength considerations of ditching provisions must be in accordance with CS 25.801(e).

FATIGUE EVALUATION

CS 25.571 Damage tolerance and fatigue evaluation of structure

ED Decision 2017/015/R

(See AMC 25.571)

(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, manufacturing defects, environmental deterioration, or accidental damage, will be avoided throughout the operational life of the aeroplane. This evaluation must be conducted in accordance with the provisions of subparagraphs (b) of this paragraph, except as specified in subparagraph (a)(4) of this paragraph, for each part of the structure that could contribute to a catastrophic failure. Additionally, a discrete source damage evaluation must be conducted in accordance with subparagraph (e) of this paragraph, and those parts which could contribute to a catastrophic failure must also be evaluated in accordance with subparagraph (d) of this paragraph. In addition, the following apply:

(1) The evaluations of subparagraphs (b) and (c) must include:

(i) The typical loading spectra, temperatures, and humidities expected in service;

(ii) The identification of principal structural elements and detail design points, the failure of which could contribute to a catastrophic failure of the aeroplane; and

(iii) An analysis, supported by test evidence, of the principal structural elements and detail design points identified in sub-paragraph (a)(1)(ii) of this paragraph.

(2) The service history of aeroplanes of similar structural design, taking due account of differences in operating conditions and procedures, may be used in the evaluations required by this paragraph.

(3) Based on the evaluations required by this paragraph, 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. The limit of validity of the engineering data that supports the structural maintenance programme (hereafter referred to as LOV), stated as a number of total accumulated flight cycles or flight hours or both, established by this paragraph, must also be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness.

(4) If the results of the evaluation required by subparagraph (b) show that damage tolerance-based inspections are impractical, then an evaluation must be performed in accordance with the provisions of subparagraph (c).

If the results of the evaluation show that damage tolerance-based inspections are practical, then inspection thresholds must be established for all principal structural elements and detail design points. For the following types of structure, the threshold must be established based on analyses and/or tests, assuming the structure contains an initial flaw representative of a defect or damage of the maximum probable size that could exist as a result of manufacturing processes or manufacturing or service-induced damage:

(i) single load path structure; and

(ii) multiple load path 'fail-safe' structure and crack arrest 'fail-safe' structure, where it cannot be demonstrated that the resulting load path failure or partial failure (including arrested cracks) will be detected and repaired during normal maintenance, inspection, or operation of an aeroplane prior to failure of the remaining structure.

(5) Inspection programmes must be established to protect the structure evaluated under subparagraph (b) and (c) against the effects of environmental deterioration and service-induced accidental damage. In addition, a baseline corrosion and prevention control programme (CPCP) must be established. The Airworthiness Limitations Section of the Instructions for Continued Airworthiness must include a statement that requires the operator to include a CPCP in their maintenance programme that will control corrosion to Level 1 or better.

(b) Fatigue and damage tolerance evaluation. The evaluation must include a determination of the probable locations and modes of damage due to fatigue, environmental deterioration (e.g. corrosion), or accidental damage. Repeated load and static analyses, supported by test evidence and (if available) service experience, must be incorporated in the evaluation. Damage at multiple sites due to prior fatigue exposure (including special consideration of widespread fatigue damage) must be included in the evaluation where the design is such that this type of damage could occur. An LOV must be established that corresponds to the period of time, stated as a number of total accumulated flight cycles or flight hours or both, for which it has been demonstrated by full-scale fatigue test evidence that widespread fatigue damage will not occur in the aeroplane structure.

The type certificate may be issued prior to completion of the full-scale fatigue testing provided that EASA has approved a plan for completing the required tests and analyses, and that at least one calendar year of safe operation has been substantiated at the time of type certification. In addition, the Airworthiness Limitations Section of the Instructions for Continued Airworthiness must specify an interim limitation restricting aircraft operation to not more than half the number of the flight cycles or flight hours accumulated on the fatigue test article, until such testing is completed, freedom from widespread fatigue damage has been established and the LOV is approved.

The extent of damage for residual strength evaluation at any time within the operational life of the aeroplane must be consistent with the initial detectability and subsequent growth under repeated loads. The residual strength evaluation must show that the remaining structure is able to withstand loads (considered as static ultimate loads) corresponding to the following conditions:

(1) The limit symmetrical manoeuvring conditions specified in CS 25.331 at all speeds up to VC and in CS 25.345.

(2) The limit gust conditions specified in CS 25.341 at the specified speeds up to V_C and in CS 25.345.

(3) The limit rolling conditions specified in CS 25.349 and the limit unsymmetrical conditions specified in CS 25.367 and CS 25.427(a) through (c), at speeds up to V_C.

(4) The limit yaw manoeuvring conditions specified in CS 25.351 at the specified speeds up to V_C.

(5) For pressurised cabins, the following conditions:

(i) The normal operating differential pressure combined with the expected external aerodynamic pressures applied simultaneously with the flight loading conditions specified in sub-paragraphs (b)(1) to (b)(4) of this paragraph if they have a significant effect.

(ii) The maximum value of normal operating differential pressure (including the expected external aerodynamic pressures during 1 g level flight) multiplied by a factor of 1·15 omitting other loads.

(6) For landing gear and other affected airframe structure, the limit ground loading conditions specified in CS 25.473, CS 25.491 and CS 25.493.

If significant changes in structural stiffness or geometry, or both, follow from a structural failure, or partial failure, the effect on damage tolerance must be further evaluated.

(c) *Fatigue (safe-life) evaluation*. Compliance with the damage-tolerance requirements of sub-paragraph (b) of this paragraph is not required if the applicant establishes that their application for particular structure is impractical. This structure must be shown by analysis, supported by test evidence, to be able to withstand the repeated loads of variable magnitude expected during its service life without detectable cracks. Appropriate safe-life scatter factors must be applied. Until such time as all testing that is required for compliance with this subparagraph is completed, the replacement times provided in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness may not exceed the total accumulated flight cycles on the test article test life divided by the applicable scatter factor.

(d) *Sonic fatigue strength.* It must be shown by analysis, supported by test evidence, or by the service history of aeroplanes of similar structural design and sonic excitation environment, that:

(1) Sonic fatigue cracks are not probable in any part of the flight structure subject to sonic excitation; or

(2) Catastrophic failure caused by sonic fatigue cracks is not probable assuming that the loads prescribed in sub-paragraph (b) of this paragraph are applied to all areas affected by those cracks.

(e) *Discrete source* damage tolerance *evaluation.* The aeroplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of bird impact as specified in CS 25.631.

The damaged structure must be able to withstand the static loads (considered as ultimate loads) which are reasonably expected to occur at the time of the occurrence and during the completion of the flight. Dynamic effects on these static loads do not need to be considered. Corrective action to be taken by the pilot following the incident, such as limiting manoeuvres, avoiding turbulence, and reducing speed, may be considered. If significant changes in structural stiffness or geometry, or both, follow from a structural failure or partial failure, the effect on damage tolerance must be further investigated.

[Amdt 25/18]
[Amdt 25/19]

AMC 25.571 Damage tolerance and fatigue evaluation of structure

ED Decision 2017/017/R

1. PURPOSE

This AMC provides guidance for compliance with the provisions of CS 25.571 pertaining to the damage tolerance and fatigue evaluation requirements for aeroplane metallic and non-metallic structure. It also provides rational guidelines for the evaluation of scatter factors for the determination of life limits for parts categorised as safe-life. Additional guidance material for certification of non-metallic structures that must also comply with CS 25.571 is contained in AMC 20-29.

2. (RESERVED)

3. REFERENCES

CS 25.571 Damage tolerance and fatigue evaluation of structure,

CS 25.1529 Instructions for Continued Airworthiness,

AMC 20-20 Continued Structural Integrity Programme,

AMC 20-29 Composite Structure.

4. DEFINITIONS OF TERMS USED IN THIS AMC

'Damage tolerance' is the attribute of the structure that permits it to retain its required residual strength without detrimental structural deformation for a period of use after the structure has sustained a given level of fatigue, environmental, accidental, or discrete source damage.

'Fatigue critical structure (FCS)' is structure that is susceptible to fatigue cracking that could lead to a catastrophic failure of an aircraft.

'Safe-life' of a structure is that number of events such as flights, landings, or flight hours, during which there is a low probability that the strength will degrade below its design ultimate value due to fatigue cracking.

'Design service goal (DSG)' is the period of time (in flight cycles or flight hours, or both) established at design and/or certification during which the aircraft structure is reasonably free from significant cracking.

'Principal structure element (PSE)' is an element that contributes significantly to the carrying of flight, ground, or pressurisation loads, and whose integrity is essential in maintaining the overall structural integrity of the aeroplane.

'Detail design point (DDP)' is an area of structure that contributes to the susceptibility of the structure to fatigue cracking or degradation such that the structure cannot maintain its load carrying capability, which could lead to a catastrophic failure.

In 'single load path structure' the applied loads are carried through a single structural member, the failure of which would result in the loss of the structural capability to carry the applied loads.

In 'multiple load path structure' the applied loads are distributed through redundant structural members so that the failure of a single structural member does not result in the loss of structural capability to carry the applied loads.

'Widespread fatigue damage (WFD)' in a structure is characterised by the simultaneous presence of cracks at multiple structural details that are of sufficient size and density whereby the structure will no longer meet the residual strength requirement of CS 25.571(b).

(1) 'Multiple site damage (MSD)' is a source of widespread fatigue damage characterised by the simultaneous presence of fatigue cracks in the same structural element.

(2) 'Multiple element damage (MED)' is a source of widespread fatigue damage characterised by the simultaneous presence of fatigue cracks in adjacent structural elements.

(3) 'Structural modification point (SMP)' is the point in time when a structural area must be modified to preclude WFD.

(4) 'Inspection start point (ISP)' is the point in time when special inspections of the fleet are initiated due to a specific probability of having an MSD/MED condition.

'Scatter factor' is a life reduction factor used in the interpretation of fatigue analysis and fatigue test results.

'Limit of validity' (LOV) of the engineering data that supports the structural maintenance programme is not more than the period of time, stated as a number of total accumulated flight cycles or flight hours or both, during which it is demonstrated by test evidence, analysis and, if available, service experience and teardown inspection results of high-time aeroplanes, that widespread fatigue damage will not occur in the aeroplane structure

'Normal maintenance' is understood to be those scheduled maintenance checks during minor or base maintenance inputs requiring general visual inspections and is normally associated with a zonal programme. The zonal programme is a collective term comprising selected general visual inspections and visual checks that are applied to each zone, defined by access and area, to check system and power plant installations and structure for security and general condition. A general visual inspection is a visual examination of an interior or exterior area, installation, or assembly to detect obvious damage, failure, or irregularity. This level of inspection is made from within touching distance unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight, or droplight and may require removal or opening of access panels or doors. Stands, ladders, or platforms may be required to gain access.

'Teardown inspection' is the process of disassembling structure and using destructive inspection techniques or visual (magnified glass and dye penetrant) or other, and non-destructive inspection methods (eddy current, ultrasonic) to identify the extent of damage, within a structure, caused by fatigue, environmental and accidental damage.

'Fail-safe' is the attribute of the structure that permits it to retain its required residual strength for a period of unrepaired use after the failure or partial failure of a principal structural element.

'$\text{WFD}_{\text{(average behaviour)}}$' is the point in time when, without intervention, 50 % of the fleet is expected to develop WFD for a particular structure.

'Level 1 corrosion' is:

damage occurring between successive inspections that is within allowable damage limits; or

damage occurring between successive inspections that does not require structural reinforcement, replacement or new damage tolerance based inspections; or

corrosion occurring between successive inspections that exceeds allowable limits but can be attributed to an event not typical of operator usage of other aircraft in the same fleet; or

light corrosion occurring repeatedly between inspections that eventually requires structural reinforcement, replacement, or new damage-tolerance-based inspections.

5. BACKGROUND

(a) Since the early 1970s, there have been significant state-of-the-art and industry-practice developments in the area of structural fatigue and fail-safe strength evaluation of transport category aeroplanes. Recognising that these developments could warrant some revision of the existing fatigue requirements of § 25.571 and 25.573 of 14 CFR Part 25, the Federal Aviation Administration (FAA), on 18 November 1976 (41 FR 50956), gave notice of the Transport Category Aeroplane Fatigue Regulatory Review Programme and invited interested persons to submit proposals to amend those requirements. The proposals and related discussions formed the basis for the revision of the structural fatigue evaluation standards of § 25.571 and § 25.573 of 14 CFR Part 25 and the development of guidance material. To that end, § 25.571 was revised, § 25.573 was deleted (the scope of § 25.571 was expanded to cover the substance of the deleted section), and guidance material (FAA AC 25.571-1) was provided which contained compliance provisions related to the proposed changes.

(b) Since the issuance of FAA AC 25.571-1 on 28 September 1978, additional guidance material, including information regarding discrete source damage, was developed and incorporated in revision 1A on 5 March 1986. The AC was further revised on 18.2.1997 (revision 1B) to add guidance on the elements to be considered in developing safe-life scatter factors for certification. Although FAR, JAR, and CS 25.571 have, since 1978, required consideration of fatigue damage originating at multiple sites, the FAA AC was further revised on 29 April 1998 (revision 1C) to add guidance material whose objective was to preclude widespread fatigue damage (resulting from MSD or MED) from occurring within the design service goal of the aeroplane, and to aid in the determination of thresholds for fatigue inspection and/or other special fleet actions. JAR/CS 25.571 were not harmonised with the 1998 amendment of 14 CFR 25.571. Under the auspices of the Aviation Rulemaking Advisory Committee (ARAC), the General Structure Harmonization Working Group (GSHWG) drafted NPA 25C-292 proposing the Limit of Validity (LOV), greater emphasis on testing, corrosion and manufacturing, and accidental damage in the 25.571 requirements and corresponding AC material to support this. EASA AMC 20-20 'Continuing Structural Integrity Programme' introduced the LOV-concept in 2007. AC 25.571-1D, issued on 13 January 2011, provides guidance in support of 14 CFR 25 Amdt 132 which introduced the LOV requirement. Thus, AMC 25.571 has been revised to provide guidance for establishing an LOV for the structural maintenance programme as will now be required by CS 25.571. In conclusion, this AMC revision based on the GSHWG work and recently developed FAA guidance, now better harmonises with the EASA guidance, AC 25.571-1D, and industry practice.

6. INTRODUCTION

(a) General

The content of this AMC is considered by EASA in determining compliance with the requirements of CS 25.571. The objective is to prevent catastrophic structural failures caused by fatigue damage (FD) (including e.g. widespread fatigue damage (WFD)), environmental deterioration (ED) (e.g. corrosion damage), or accidental damage (AD).

Compliance involves good design practice to ensure that damage tolerance can be achieved and the establishment of maintenance actions developed in compliance with CS 25.1529. Taken together, they result in a structure where the combination of design characteristics and maintenance actions will serve to preclude any failure due to FD, ED, or AD.

CS 25.571(a)(3) requires the applicant to establish inspections or other procedures (herein also referred to as maintenance actions) as necessary to avoid catastrophic failure during the operational life of the aeroplane based on the results of the prescribed fatigue and damage tolerance evaluations.

CS 25.571(a)(5) requires development of inspections for ED and AD. CS 25.571(b) requires the applicant to establish an LOV. Furthermore, CS 25.571(b) and (c) require establishment of inspections and replacement times respectively based on the damage tolerance and fatigue characteristics of the structure. The LOV is, in effect, the operational life of the aeroplane consistent with the evaluations accomplished and maintenance actions established to prevent WFD. The LOV is established based on WFD considerations and it is intended that all maintenance actions required to address fatigue damage, environmental deterioration (e.g. corrosion damage for metallics, moisture for composites), and accidental damage (e.g. impact, lightning), up to the LOV, are identified in the structural maintenance programme. All inspections and other procedures (e.g. modification times, replacement times) that are necessary to prevent a catastrophic failure due to fatigue, up to the LOV, must be included in the Airworthiness Limitations Section (ALS) of the Instructions for Continued Airworthiness (ICA), as required by CS 25.1529, along with the LOV.

CS 25.571(d) requires the structure to be designed such that sonic fatigue cracking is not probable or, if it arises, it will not result in a catastrophic failure. CS 25.571(e) requires the structure to be designed to withstand damage caused by specified threats such that the flight during which the damage is sustained can be completed.

(1) *CS 25.571(a)(5) — Environmental and accidental damage inspections and associated procedures*

Inspections for ED and AD must be defined. Special consideration should be given to those areas where past service experience indicates a particular susceptibility to attack by the environment or vulnerability to impact and/or abuse. It is intended that these inspections will be effective in discovering ED or AD before it interacts with fatigue related phenomena, and that the ED or AD will, therefore, be removed/repaired before it presents a significant risk. Typically these inspections are largely defined based on past service experience using a qualitative or quantitative process in combination with the Airline Transportation Association (ATA) Maintenance Steering Group (MSG)-3 process. For new structure and materials, testing may be required to evaluate likely AD and the subsequent tolerance of the design to it. For ED prevention, an effective CPCP is necessary, which will contain tasks and procedures in addition to inspections that will help prevent initiation and, when necessary, the recurrence of corrosion (see AMC 20-20). Furthermore, CS 25.571 requires that the ALS must include a statement that requires the operator to include a CPCP in their maintenance programme that will control the corrosion to Level 1 or better.

Any special inspections required for AD and ED, i.e. ones in addition to those that would be generated through the use of the MSG-3 process for AD and ED, or the baseline CPCP development, and which are necessary to prevent catastrophic failure of the aeroplane, must be included in the ALS of the ICA required by CS 25.1529. If a location is prone to accidental or environmental damage and the only means for detection is one that relies on the subsequent development of a fatigue crack from the original damage, then that inspection must be placed in the ALS of the ICA.

Note: The AD and ED inspection programme including the baseline CPCP are equally applicable to structures showing compliance with CS 25.571(b) and (c) respectively.

(2) *CS 25.571(b) and (c) — Fatigue damage inspections or replacement times*

Inspections for fatigue damage or replacement times must be established as necessary. These actions must be based on quantitative evaluations of the fatigue characteristics of the structure. In general, analysis and testing will be required to generate the information needed. The applicant should perform crack growth and residual strength testing to produce the design data needed to support crack growth and residual strength analyses. Full-scale fatigue test evidence is required to support the evaluation of structure that is susceptible to WFD. Test evidence is needed to support analysis used to establish safe-life replacement times.

(i) Inspection or replacement

Compliance with CS 25.571(b) is required unless it can be demonstrated to the satisfaction of the authority that compliance cannot be shown due to practical constraints. Under these circumstances, compliance with CS 25.571(c) is required. The only common example of structure where compliance with the requirements of CS 25.571(c), in lieu of CS 25.571(b), might be accepted, would be the landing gear and its local attachments.

(ii) ALS of the ICA

All inspections and replacement times necessary to detect or preclude fatigue cracking scenarios, before they become critical, must be included in the ALS of the ICA required by CS 25.1529.

(iii) Limit of Validity (LOV)

An LOV for the structural maintenance programme must also be determined and included in the ALS of the ICA. See section 11 of this AMC for additional guidance on the LOV.

(b) Typical loading spectrum expected in service

The loading spectrum should be based on measured statistical data of the type derived from government and industry load history studies, and where insufficient data are available on a conservative estimate of the anticipated use of the aeroplane. The development of the loading spectrum includes the definition of the expected flight plan, which involves ground manoeuvres, climb, cruise, descent, flight times, operating speeds, weights and altitudes, and the approximate time to be spent in each of the operating regimes. The principal loads that should be considered in establishing a loading spectrum are flight loads (gust and manoeuvre), ground loads (taxiing, landing impact, turning, engine run-up, braking, thrust reversing and towing), and pressurisation loads. Operations for crew training and other pertinent factors, such as the dynamic stress characteristics of any flexible structure excited by turbulence or buffeting, should also be considered. For pressurised cabins, the loading spectrum should include the repeated application of the normal operating differential pressure and the superimposed effects of flight loads and aerodynamic pressures.

(c) Areas to be evaluated

When assessing the possibility of serious fatigue failures, the design should be examined to determine probable points of failure in service. In this examination consideration should be given, as necessary, to the results of stress analyses, static tests, fatigue tests, strain gauge surveys, tests of similar structural configurations, and service experience. Service experience has shown that special attention should be focused on the design details of important discontinuities, main attach fittings, tension joints, splices, and cut-outs such as windows, doors, and other openings. Locations prone to accidental damage (such as that due to the impact with ground servicing equipment near aeroplane doors) or to corrosion should be identified for analysis.

(d) Analyses and tests

Fatigue and damage tolerance analyses should be conducted unless it is determined that the normal operating stresses are of such a low order that crack initiation and, where applicable, significant damage growth is extremely improbable. Any method used in the analyses should be supported by test or service experience. Typical (average) values of fatigue respectively fracture mechanics material properties may be used in fatigue analysis respectively residual strength and crack growth analyses. The effects of environment on these properties should be accounted for if significant.

Generally, testing will also be necessary to support compliance with CS 25.571(b) or (c). The nature and extent of testing of complete structures or portions will depend on applicable previous design and structural tests and service experience with similar structures. Structural areas such as attachment fittings, major joints, changes in section, cut-outs, and discontinuities almost always require some level of testing in addition to analysis. When less than the complete structure is tested, care should be taken to ensure that the internal loads and boundary conditions are valid. When tests are conducted to support the identification of areas susceptible to fatigue, the duration of the test should take into account factors such as material and loading spectrum variability, together with the expected operational life. Refer to Appendix 2 for specific guidance regarding testing required to establish the LOV.

(e) Discrete source damage

It must be shown that the aeroplane is capable of successfully completing a flight during which specified incidents occur and result in immediately obvious damage. The maximum extent of the damage must be quantified and the structure must be shown to be capable of sustaining the maximum load (considered as ultimate) expected during the completion of the flight. There are no maintenance actions that result from this evaluation.

7. DAMAGE TOLERANCE EVALUATION

(a) General

The damage tolerance requirements of CS 25.571(b) are intended to ensure that, should fatigue, corrosion, or accidental damage occur within the LOV, the structure will be capable of withstanding the loading conditions specified in CS 25.571(b)(1) through (b)(6) without failure or detrimental structural deformation until the damage is detected. The evaluation should include identifying the PSEs, defining the loading conditions and conducting sufficiently representative structural tests or analyses, or both, to provide sufficient data for the establishment of the inspection programme. Although this process applies to either single or multiple load path structure, the use of multiple load path structures should be given priority in achieving a damage-tolerant design. The principle analytical tool used for metallic materials to perform a damage tolerance evaluation is based on fracture mechanics. A discussion of this approach is presented in Appendix 1 of this guidance material. The means of establishing the LOV and maintenance actions specifically associated to WFD is addressed in detail in Section 11 of this AMC.