Designation: F3115/F3115M – 15

Standard Specification for Structural Durability for Small Airplanes[1]

This standard is issued under the fixed designation F3115/F3115M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification addresses the airworthiness requirements related to structural durability for the design of small airplanes.

1.2 This specification was originally conceived for small airplanes as defined in the F44 terminology standard but may find broader applicability. Use of the term aircraft throughout this specification is intended to allow the relevant CAA(s) to accept this standard as a means of compliance as they determine it to be appropriate, whether for small airplanes or for other types of aircraft.

1.3 The applicant for a design approval must seek individual guidance from their respective CAA body concerning the use of this standard as part of a certification plan. For information on which CAA regulatory bodies have accepted this standard (in whole or in part) as a means of compliance to their Small Airplane Airworthiness Rules (hereinafter referred to as "the Rules"), refer to ASTM F44 webpage (www.ASTM.org/COMMITTEE/F44.htm) which includes CAA website links.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
F3060 Terminology for Aircraft

2.2 *Federal Aviation Regulations:*[3]
14 CFR Part 23 Amendment 62, §§ 23.571 through 23.575, 23.627

2.3 *EASA Requirements:*
CS 23, §§ 23.571 through 23.575
CS-VLA

3. Terminology

3.1 The following are a selection of relevant terms. See Terminology F3060 for more definitions and abbreviations.

3.2 *Definitions:*

3.2.1 *fatigue*—the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points, which may result in cracks or complete fracture after a sufficient number of fluctuations.

3.2.2 *safe life*—the 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.

3.2.3 *S-N or* ε-*N*—Stress-Life (S-N) or Strain-Life (ε-N) curves depict the magnitude of applied stress (S) or strain (ε) necessary to develop a fatigue crack in a specimen at a given life (N), where N is expressed in the number of cyclic applications of stress or strain.

3.2.4 *scatter factor*—the scatter factor, or life reduction factor, is a statistically derived divisor applied to fatigue test results to account for the variation in fatigue performance of built-up or monolithic structures and usage variability. A scatter factor can also be used in a fatigue analysis to address the uncertainties inherent in a fatigue analysis.

3.2.5 *fail safe*—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.

3.2.6 *damage tolerance*—damage tolerance is the attribute of the structure that permits it to retain its required residual

[1] This specification is under the jurisdiction of ASTM Committee F44 on General Aviation Aircraft and is the direct responsibility of Subcommittee F44.30 on Structures.

Current edition approved June 1, 2015. Published September 2015. DOI: 10.1520/F3115_F3115M-15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

strength for a period of use after the structure has sustained a given level of fatigue, corrosion, accidental, or discrete source damage.

3.2.7 *residual strength*—the strength capability of a structure after the structure has been damaged due to fatigue, corrosion, or discrete source damage. The residual strength capability includes consideration of static strength, fracture, and stiffness.

4. Metallic Structure

4.1 The structural components listed in 4.2 and 4.3 must be shown to be able to withstand the repeated loads of variable magnitude expected in service.

4.2 *Pressurized Cabin Structures:*

4.2.1 *Certificated for Operation up to 12 500 m [41 000 ft]*—The strength, detail design, and fabrication of the metallic structure of the pressure cabin must be evaluated using one of the following methods:

4.2.1.1 For Level I, II and III airplanes, the methods described in 4.4, 4.5, or 4.6.

4.2.1.2 For Level IV airplanes, the method described in 4.6.

4.2.2 *Certificated for Operation above 12 500 m [41 000 ft]*—If certification for operation above 12 500 m [41 000 ft] is requested, the damage tolerance evaluation of 4.6, must be conducted for the fuselage pressure boundary.

4.3 *Wing, Empennage, and Associated Structures:*

4.3.1 The strength, detail design, and fabrication of those parts of the airframe structure whose failure would be catastrophic must be evaluated using one of the following evaluations unless it is shown that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience.

4.3.1.1 For Level I, II, and III airplanes, the methods described in 4.4, 4.5, or 4.6.

4.3.1.2 For Level IV airplanes, the evaluation described in 4.6.

4.3.2 The evaluation required in 4.3 must:

4.3.2.1 Include typical loading spectra (for example, taxi, ground-air-ground cycles, maneuver, gust);

4.3.2.2 Account for any significant effects due to the mutual influence of aerodynamic surfaces; and

4.3.2.3 Consider any significant effects from propeller slipstream loading, and buffet from vortex impingements.

4.4 *Fatigue Strength Evaluation*—An evaluation in which the structure is shown by tests, or by analysis supported by test evidence, to be able to withstand the repeated loads of variable magnitude expected in service. The safe life limit shall be the mean demonstrated cyclic test life divided by appropriate scatter factors.

4.4.1 *For Unpressurized Level I Airplanes*—There must be sufficient evidence that safety critical parts have strength capabilities to achieve an adequate safe-life. Safety critical parts are primary structure, the failure of which can be regarded as safety critical and which could endanger the occupants or lead to loss of the airplane, or both. Sufficient evidence may be in the form of demonstrated low stress levels which are based on fatigue test data for similar structural configuration and material.

4.5 *Fail Safe Strength Evaluation*—An evaluation in which it is shown by analysis, tests, or both, that catastrophic failure of the structure is not probable after fatigue failure, or obvious partial failure, of a principal structural element and that the remaining structure is able to withstand the residual strength loads in 4.7.1. Additional procedures must be used to prevent loss of fail-safe capability or continued operation with damaged structural components.

4.6 *Damage Tolerance Evaluation*—An evaluation that includes a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. Modes of damage should be identified in the analysis to show the extent of damage evaluated. The determination must be by analysis supported by test evidence and, if available, service experience. Damage at multiple sites due to fatigue must be included where the design is such that this type of damage can be expected to occur. The evaluation must incorporate repeated load and static analyses supported by test evidence. The extent of damage for residual strength evaluation at any time within the operational life of the airplane 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 the residual stength loads in 4.7 with the extent of detectable damage consistent with the results of the damage tolerance evaluations. If the applicant establishes that damage-tolerance criteria is impractical for a particular structure, the structure must be evaluated in accordance with 4.4.

4.7 *Residual Strength*—For damage tolerance evaluations, the remaining structure must be able to withstand the loads identified in 4.7.1 through 4.7.3. The load requirements are also applicable to the fail safe evaluation in 4.5.

4.7.1 Critical limit flight loads, considered as ultimate,

4.7.2 In addition to 4.7.1, for pressurized cabin structures, the normal operating differential pressure combined with the expected external aerodynamic pressures applied simultaneously with the flight loading conditions specified in F44, and [23.573(b)(1)].

4.7.3 In addition to 4.7.1, for pressurized cabin structures, the expected external aerodynamic pressures in 1g flight combined with a cabin differential pressure equal to 1.1× the normal operating differential pressure without any other load.

5. Composite Structure

5.1 Composite airframe structure must be evaluated under this paragraph instead of Section 4. The applicant must evaluate the composite airframe structure, the failure of which would result in catastrophic loss of the airplane, in each wing (including canards, tandem wings, and winglets), empennage, their carrythrough and attaching structure, moveable control surfaces and their attaching structure, fuselage, and pressure cabin using the damage tolerance criteria prescribed in 5.2. If the applicant establishes that damage-tolerance criteria is impractical for a particular structure, the structure must be evaluated in accordance with 5.3. Where bonded joints are

used, the structure must also be evaluated in accordance with Section 6. The effects of material variability and environmental conditions on the strength and durability properties of the composite materials must be accounted for in the evaluations required by this section.

5.2 *Damage Tolerance Evaluation:*

5.2.1 It must be demonstrated by tests, or by analysis supported by tests, that the structure is capable of carrying ultimate load with damage up to the threshold of detectability considering the inspection procedures employed.

5.2.2 The growth rate or no-growth of damage that may occur from fatigue, corrosion, manufacturing flaws or impact damage, under repeated loads expected in service, must be established by tests or analysis supported by tests.

5.2.3 The structure must be shown by residual strength tests, or analysis supported by residual strength tests, to be able to withstand critical limit flight loads, considered as ultimate loads, with the extent of detectable damage consistent with the results of the damage tolerance evaluations. For pressurized cabins, the following loads must be withstood:

5.2.3.1 Critical limit flight loads with the combined effects of normal operating pressure and expected external aerodynamic pressures.

5.2.3.2 The expected external aerodynamic pressures in 1g flight combined with a cabin differential pressure equal to 1.1 times the normal operating differential pressure without any other load.

5.2.4 The damage growth, between initial detectability and the value selected for residual strength demonstrations, factored to obtain inspection intervals, must allow development of an inspection program suitable for application by operation and maintenance personnel.

5.3 *Fatigue Strength Evaluation:*

5.3.1 It must be demonstrated by tests, or by analysis supported by tests, that the structure is capable of carrying ultimate load with damage up to the threshold of detectability considering the inspection procedures employed.

5.3.2 Structural components for which the damage tolerance method is shown to be impractical must be shown by component fatigue tests, or analysis supported by tests, to be able to withstand the repeated loads of variable magnitude expected in service. Sufficient component, subcomponent, element, or coupon tests must be done to establish the fatigue scatter factor and the environmental effects. Damage up to the threshold of detectability and ultimate load residual strength capability must be considered in the demonstration. A safe life limit shall be established, by test, using appropriate Load Enhancement Factors (LEF) and Life Factors (N).

6. Bonded Structure Residual Strength

6.1 For composite airframe structure on Level II, III, and IV aircraft, the residual strength of bonded joints needs to be addressed as follows: for any bonded joint, the failure of which would result in catastrophic loss of the airplane, the limit load capacity must be substantiated by one of the following methods.

6.1.1 The maximum disbonds of each bonded joint consistent with the capability to withstand the residual strength loads in 4.7 or 5.2.3 must be determined by analysis, tests, or both. Disbonds of each bonded joint greater than this must be prevented by design features; or

6.1.2 Proof testing must be conducted on each production article that will apply the critical limit design load to each critical bonded joint; or

6.1.3 Repeatable and reliable non-destructive inspection techniques must be established that ensure the strength of each joint.

7. Inspections and Other Procedures

7.1 Each inspection or other procedure required to demonstrate compliance to this standard must be included in the Limitations Section of the Instructions for Continued Airworthiness required by F44 [§ 23.1529].