European Aviation Safety Agency

10 Jul 2009

NOTICE OF PROPOSED AMENDMENT (NPA) NO 2009-06

DRAFT DECISION OF THE EXECUTIVE DIRECTOR OF THE EUROPEAN AVIATION SAFETY AGENCY

Amending Decision No. 2003/14/RM of the Executive Director of the European Aviation Safety Agency of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for normal, utility, aerobatic and commuter category aeroplanes (« CS-23 »)

and

Amending Decision No. 2003/2/RM of the Executive Director of the European Aviation Safety Agency of 17 October 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for large aeroplanes (« CS-25 »)

and

Amending Decision No. 2003/15/RM of the Executive Director of the European Aviation Safety Agency of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for small rotorcraft (« CS-27 »)

and

Amending Decision No. 2003/16/RM of the Executive Director of the European Aviation Safety Agency of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for large rotorcraft (« CS-29 »)

and

Amending Decision No. 2003/12/RM of the Executive Director of the European Aviation Safety Agency of 5 November 2003 on general acceptable means of compliance for airworthiness of products, parts and appliances (« AMC-20 »)

"Composites"

TABLE OF CONTENTS

A. Explanatory Note

I. General

1. The purpose of this Notice of Proposed Amendment (NPA) is to envisage amending Decision 2003/14/RM of the Executive Director of 14 November 2003[1], Decision 2003/2/RM of the Executive Director of 17 October 2003[2], Decision 2003/15/RM of the Executive Director of 14 November 2003[3], Decision 2003/16/RM of the Executive Director of 14 November 2003[4] and Decision 2003/12/RM of the Executive Director of 5 November 2003[5]. The scope of this rulemaking activity is outlined in Terms of Reference MDM.034 and is described in more detail below.
2. The European Aviation Safety Agency (hereinafter referred to as the Agency) is directly involved in the rule-shaping process. It assists the Commission in its executive tasks by preparing draft regulations, and amendments thereof, for the implementation of the Basic Regulation[6] which are adopted as "Opinions" (Article 19(1)). It also adopts Certification Specifications, including Airworthiness Codes and Acceptable Means of Compliance and Guidance Material to be used in the certification process (Article 19(2)).
3. When developing rules, the Agency is bound to follow a structured process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as "The Rulemaking Procedure"[7].
4. This rulemaking activity is included in the Agency's Rulemaking Programme for 2010. It implements the rulemaking task MDM.034 on Composites.
5. The text of this NPA has been developed by the Agency based on drafts produced by the international CMH-17 Volume 3 Working Group. It is technically equivalent and harmonised with FAA AC20-107B. It is submitted for consultation of all interested parties in accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

II. Consultation

6. To achieve optimal consultation, the Agency is publishing the draft decision of the Executive Director on its internet site. Comments should be provided within 3 months. Comments on this proposal should be submitted by one of the following methods:

CRT:	Send your comments using the Comment-Response Tool (CRT) available at **http://hub.easa.europa.eu/crt/**

---

[1] Decision No 2003/14/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications, including airworthiness codes and acceptable means of compliance for normal, utility, aerobatic and commuter category aeroplanes (« CS-23 »). Decision as last amended by Decision 2009/001/R of the Executive Director of the Agency of 12 February 2009.

[2] Decision No 2003/2/RM of the Executive Director of the Agency of 17.10.2003 on certification specifications, including airworthiness codes and acceptable means of compliance for large aeroplanes (« CS-25 »). Decision as last amended by Decision 2009/010/R of the Executive Director of the Agency of 26 June 2009.

[3] Decision No 2003/15/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications, including airworthiness codes and acceptable means of compliance for small rotorcraft. Decision as last amended by Decision 2008/09/R of the Executive Director of the Agency of 17 November 2008.

[4] Decision No 2003/16/RM of the Executive Director of the Agency of 14.11.2003 on certification specifications, including airworthiness codes and acceptable means of compliance for large rotorcraft. Decision as last amended by Decision 2008/10/R of the Executive Director of the Agency of 17 November 2008.

[5] Decision No 2003/12/RM of the Executive Director of the Agency of 5.11.2003 on general acceptable means of compliance for airworthiness of products, parts and appliances. Decision as last amended by Decision 2008/007/R of the Executive Director of the Agency of 5 September 2008.

[6] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.03.2008, p. 1)

[7] Management Board decision concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material (Rulemaking Procedure), EASA MB 08-2007, 13.6.2007

E-mail:	In case the use of CRT is prevented by technical problems these should be reported to the CRT webmaster and comments sent by email to NPA@easa.europa.eu.
Correspondence:	If you do not have access to internet or e-mail you can send your comment by mail to: Process Support Rulemaking Directorate EASA Postfach 10 12 53 D-50452 Cologne Germany

Comments should be submitted **by 13 October 2009.** If received after this deadline they might not be taken into account.

III. Comment response document

7. All comments received in time will be responded to and incorporated in a comment response document (CRD). The CRD will be available on the Agency's website and in the Comment-Response Tool (CRT).

IV. Content of the draft decision

8. Existing AMC to CS-23/25/27/29.603[8] provides acceptable means of compliance and guidance for the design, construction, quality control and repair of composite structures, including the suitability and durability of materials and their methods of fabrication. With the significant increased use of composite materials and technology in aircraft structures, including primary structure, much of this AMC is no longer directly applicable or does not adequately address advances in composite structures and technology, A pressing need has therefore arisen to update this AMC.

9. This NPA proposes to create a single new AMC-20 chapter (AMC 20-29). It will identify and standardise recognised good practice common to CS-23, 25, 27, and 29 in one document by replacing existing AMC to 23.603 and 25.603 and by complementing, but not replacing, harmonised guidance material developed for CS-27 and CS-29 (FAA AC 27-1B MG8 and AC 29-2C MG8).

10. Existing AMC currently makes reference to FAA AC 20-107A as an acceptable means of compliance and guidance. This document is in the process of being updated to AC 20-107B by the FAA and is technically harmonised with AMC 20-29. References to AC 20-107A will be replaced with references to AMC 20-29.

11. Composite materials are used in all types of aircraft and the number of paragraphs affected by the choice of material in each CS is large. Therefore, to avoid creating a network of cross-references to AMC 20-29 within the CSs, a single cross-reference is added from the general materials paragraph of CS-23/25/27/29.603 (subsequently referred to as CS 2x.603) within the design and construction Subpart (Subpart D). A list of affected CS paragraphs is then provided in Appendix 1 to AMC 20-29.

12. Many of the concepts included in this NPA may be applicable in part or in full to other CSs (e.g. CS-VLA, CS-VLR, CS-E, CS-22, etc.). However when using AMC 20-29 as an acceptable means of compliance for these other CSs, appropriate engineering judgement should be exercised and early agreement with the Agency sought.

---

[8] Including FAA AC 27-1B and AC 29-2C MG8 adopted in Book 2 of CS-27 and CS-29 respectively.

The envisaged changes include:

a) **CS-23** (Decision 2003/14/RM):

- CS 23.603 is amended to replace the reference to AMC 23.603 with a reference to AMC 20-29.
- AMC 23.573(a)(1)&(3) is amended to replace the reference to AMC 23.603 with a reference to AMC 20-29. (Minor editorial changes are also made).
- AMC 23.603 Material and workmanship Composite Aeroplane Structure (Acceptable Means of Compliance) is deleted.
- AMC 23.613 is amended to replace the reference to AMC 23.603 with a reference to AMC 20-29. (In addition the title of ML-HDBK-23 was noted as being in error and is amended).
- AMC 23.629 in amended to replace the reference to AMC 23.603 with a reference to AMC 20-29. (Minor editorial changes are also made).

b) **CS-25** (Decision 2003/02/RM):

- 25.603 is amended to add a reference to the new AMC 20-29 and references to AMC No.1 and 2 are deleted.
- AMC No.1 to CS 25.603 Composite Aircraft Structure is deleted.
- AMC No.2 to CS 25.603 Composite Aircraft Structure is deleted. (This is the basis for the new AMC 20-29 Appendix 3)

c) **CS-27** (Decision 2003/15/RM):

- 27.603 is amended to add a reference to the new AMC 20-29

Note It is envisaged that some editorial changes to AC 27-1B (AC 27.603 and MG8), will be required. This will be undertaken as part of the normal revision process for AC 27-1B, and will be the subject of a separate NPA.

d) **CS-29** (Decision 2003/16/RM):

- 29.603 is amended to add a reference to the new AMC 20-29

Note It is envisaged that some editorial changes to AC 29-2C (AC 29.603 and MG8), will be required. This will be undertaken as part of the normal revision process for AC 29-2C, and will be the subject of a separate NPA.

e) **AMC-20** (Decision 2003/12/RM):

- New AMC 20-29 on Composite Aircraft Structures is created.

V. Regulatory Impact Assessment

13. Purpose and Intended Effect

a. Issue which the NPA is intended to address

To provide common acceptable means of compliance and guidance material for composite aircraft structures to reflect the growing use of such composite structures and technology in modern aircraft.

b. Scale of the issue (quantified if possible)

As composite materials and technology is used extensively across all types of aircraft, guidance on acceptable means of compliance has general applicability.

c. Brief statement of the objectives of the NPA

The NPA is intended to introduce a new AMC 20-29 on composite aircraft structures and to amend existing CSs accordingly. This will provide designers with greater guidance on composites technology and best practice for design and continued airworthiness considerations, and enable designers to anticipate the Agency's acceptance of composite structures as part of a certification programme. AMC 20-29 is technically equivalent to FAA AC20-107B, providing a single harmonised approach to composite structure certification.

14. Options

a. The options identified

Option 1: Do nothing

If nothing is done, only limited acceptable means of compliance to CS 2x.603 for composite materials will exist, despite the extensive and widespread use of composites in aircraft structures, including the recent introduction in primary structure. Doing nothing would not provide applicants with sufficient information and knowhow to allow possible safety issues related with composites technology to be taken into account during the initial design, and may result in a non-compliance with the Agency's interpretation of the applicable airworthiness code or Special conditions. This could have a detrimental economic impact on the applicant, as will non-harmonised standards that dictate the need to perform additional compliance demonstration activities.

Option 2: Develop AMC 20-29

Providing AMC and general guidance for the design and certification of composite aircraft structures under AMC-20, will provide consistent guidance spanning all aircraft categories, and will enable designers to anticipate the Agency's acceptance of composite structures. Furthermore, providing such AMC is in accordance with the Basic Regulation (Article 19.2), which requires the Agency to develop certification specifications and guidance material to reflect the state of the art and scientific and technical progress.

b. The preferred option selected (if possible)

Please see paragraph V-14c below.

15. Sectors concerned

All aircraft manufactures designing composite structures. It will also be applicable to parts manufacturers, material suppliers, and maintenance and repair organizations.

16. Impacts

a. All identified impacts

i. Safety

Option 1 – Would not add to safety

Option 2 - Providing AMC and guidance material on composite structures and technology will contribute to safety through greater awareness of related safety issues and by identifying and promulgating best practice in the design and construction of composite structures.

ii. Economic

Option 1 – No impact

Option 2 - Defining AMC and guidance material that gives applicants prior knowledge of what is acceptable to the Agency, will enable better design planning and give the applicant confidence that a structure could be certificated. This will ensure that certification costs can be better controlled.

iii. Environmental

None identified

iv. Social

None identified

v. Other aviation requirements outside EASA scope

Linked with developments of CMH-17 Vol.3 and FAA AC 20-107B.

b. Equity and fairness in terms of distribution of positive and negative impacts among concerned sectors.

No equity and fairness issues are expected from any of the options identified. All applicants are equally affected.

17. Summary and Final Assessment

a. Comparison of the positive and negative impacts for each option evaluated

Option 1 will not provide applicants with sufficient knowledge to enable detailed certification requirements to be determined prior to design. In addition, AMC/AC may vary between different certificating Agencies, leading to multiple showings of compliance and additional costs for no or little safety benefit.

Option 2 provides for the development of more extensive, harmonised, AMC and guidance material for the design and certification of composite structures. It will aid applicants to apply best practice, aid the showing of compliance with certification specifications and minimise certification costs. The development of guidance to reflect the state of the art and technical and scientific advancement is also in line with the Agency’s mandate.

b. A summary describing who would be affected by these impacts and analysing issues of equity and fairness

All aircraft manufactures designing composite structures are affected. It will also be applicable to parts manufacturers, material suppliers, and maintenance and repair organizations. No issues of equity and fairness have been identified.

c. Final assessment and recommendation of a preferred option

Option 2: Development of AMC 20-29 is selected.

B. Draft Opinion(s) and/or Decision(s)

The text of the amendment is arranged to show deleted text, new text or new paragraph as shown below:

1. deleted text is shown with a strike through: ~~deleted~~
2. new text is highlighted with grey shading: new
3. ….

   indicates that remaining text is unchanged in front of or following the reflected amendment.

I Draft Decision CS-23

Book 1
SUBPART D Design and Construction

Amend CS 23.603 by deleting reference to AMC 23.603 and adding a reference to AMC 20-29, as follows:

CS 23.603 Materials and workmanship
(~~See AMC 23.603~~ For composite materials see AMC 20-29)

Book 2
SUBPART D Design and Construction

Delete AMC 23.603 Material and workmanship Composite Aeroplane Structure (Acceptable Means of Compliance)

Amend AMC 23.573(a)(1)&(3) to replace the reference to AMC 23.603 with a reference to AMC 20-29, as follows:

AMC 23.573(a)(1)&(3)
Damage tolerance and fatigue evaluation of structure – composite airframe structure

In addition to the acceptable means of compliance and guidance material described in ~~AMC 23.603~~ AMC 20-29 the following procedure may be adopted for residual strength tests of structure with built-in barely visible impact damage~~s~~ (BVID) and visible damage~~s~~. Tests should be performed up to limit load level, then the visible damage~~s~~ may be repaired without substantially exceeding the original strength or characteristics of the type design and the test should be continued up to at least* ultimate load level in order to validate the BVID in the unrepaired structure.

* Experience has shown that continuation of testing to rupture should be considered in order to identify failure modes. Extrapolation by analysis of residual strength tests would not normally be acceptable for further development of the aeroplane.

Amend AMC 23.613 to replace the reference to AMC 23.603 with a reference to AMC 20-29, as follows:

AMC 23.613
Metallic strength properties and design values

Material specifications should be those contained in documents accepted either specifically by the Agency or by having been prepared by an organisation or a person which the Agency accepts has the necessary capabilities.
Such specifications are for example:

1 Mil–HDBK–5 'Metallic Materials and Elements for Flight Vehicle Structure'
2 Mil–HDBK–17 'Plastics for Flight Vehicles'
3 Mil–HDBK–23 '~~Composite Construction for Flight Vehicles~~ Structural Sandwich Composites'
4 ANC–18 'Design of Wood Aircraft Structures'

In defining design properties the material specification values must be modified and/or extended as necessary by the designer to take account of manufacturing practices (e.g., methods of construction, forming, machining and subsequent heat treatment).

For composite structure ~~CS–23 AMC 23.603~~ AMC 20-29 contains acceptable means of compliance and guidance material ~~information~~ relevant to the requirements of CS 23.613.

Amend AMC 23.629 to replace the reference to AMC 23.603 with a reference to AMC 20-29, as follows:

AMC 23.629
Flutter
…
FAA Advisory Circular AC 23.629–1A and in addition for composite structures ~~CS–23 AMC 23.603,~~ AMC 20-29 provides additional ~~information and guidance concerning an~~ acceptable means of ~~demonstrating~~ compliance and guidance material to ~~with the requirements of~~ CS 23.629.

II Draft Decision CS-25

Book 1
SUBPART D Design and Construction

Amend CS 25.603 to replace the reference to AMC No. 1 and No. 2 to 25.603 with a reference to AMC 20-29, as follows:

CS 25.603 Materials (For Composite Materials see ~~AMC No. 1 and No. 2 to 25.603.~~ AMC 20-29)

Book 2
SUBPART D Design and Construction

Delete – AMC No.1 to CS 25.603 Composite Aircraft Structure

Delete – AMC No.2 to CS 25.603 Composite Aircraft Structure

III Draft Decision CS-27

Book 1
SUBPART D Design and Construction

Amend CS 27.603 by inserting a reference to AMC 20-29, as follows:

CS 27.603 Materials
(For composite materials, also see AMC 20-29)

IV Draft Decision CS-29

Book 1
SUBPART D Design and Construction

Amend CS 29.603 by inserting a reference to AMC 20-29, as follows:

CS 29.603 Materials
(For composite materials, also see AMC 20-29)

V Draft Decision AMC-20

Add a new AMC 20-29 to read as follows:

AMC 20-29 Effective: xx/xx/200x
Annex II to ED Decision 200x/xxx/R of xx/xx/200x

AMC 20-29
Composite Aircraft Structures

0. TABLE OF CONTENTS

1. PURPOSE

This AMC provides acceptable means of compliance for type-certification of composite aircraft structures involving fibre reinforced materials, e.g. carbon and glass fibre reinforced plastics. Guidance information is also presented on the closely related design, manufacturing and maintenance aspects.

2. OBJECTIVE

AMC 20-29 standardises recognised good design practices common to composite aircraft structures in one document.

For rotorcraft (CS-27 and CS-29), AMC 20-29 complements existing harmonised guidance material contained in AC 27-1B MG8 and AC 29-2C MG8, (as adopted as AMC in Book 2 of CS-27 and CS-29).

3. APPLICABILITY

This AMC provides acceptable means of compliance with the provisions of CS-23, 25, 27 and 29[9]. Many of the concepts included in this AMC may also be applicable in part or in full to other CSs (e.g. CS-VLA, CS-VLR, CS-E, CS-22, etc.). However when using this AMC as an acceptable means of compliance for these other CSs, appropriate engineering judgement should be exercised and early agreement with the Agency sought.

This AMC applies to applicants for type-certification, certificate/approval holders, parts manufacturers, material suppliers, and maintenance and repair organisations.

Note: This AMC is technically harmonised with FAA Advisory Circular AC 20-107B, dated dd MMMM 2009. (*to be completed once FAA AC is published*).

4. RELATED REGULATIONS AND GUIDANCE.

The material contained herein applies to aircraft to be type-certificated under CS-23, 25, 27, 29; and it is produced in compliance with PART 21.

a. Applicable paragraphs are listed in Appendix 1.

b. Relevant guidance considered complementary to this AMC is provided in Appendix 1.

5. GENERAL.

a. The procedures outlined in this AMC provide acceptable means of compliance and guidance material for composite structures and are considered acceptable to the Agency for showing compliance with certification requirements. This AMC is published to aid in the evaluation of certification programmes for composite applications and to reflect the

---

[9] For a list of applicable CS paragraphs applicable to this AMC see Appendix 1

current status of composite technology. It is expected that this AMC will be modified periodically to reflect the continued evolution of composite technology and the data collected from service experiences and expanding applications.

b. There are factors unique to the specific composite materials and processes used for a given application. For example, the environmental sensitivity, anisotropic properties and heterogeneous nature of composites can make the determination of Critical Structure failure loads, modes and locations difficult. The reliability of such evaluation depends on repeatable structural details created by scaled manufacturing or repair processes. The extent of testing and/or analysis may differ for a structure depending upon the criticality to flight safety, expected service usage, the material and processes selected, the design margins, the failure criteria, the database and experience with similar structures, and on other factors affecting a particular structure. It is expected that these factors will be considered when interpreting this AMC for use on a specific application.

c. Pertinent definitions are given in Appendix 2.

6. MATERIAL AND FABRICATION DEVELOPMENT.

All composite materials and processes used in Critical Structures are qualified through enough fabrication trials and tests to demonstrate a reproducible and reliable design. One of the unique features of composite construction is the degree of care needed in the procurement and processing of composite materials. The final mechanical behaviour of a given composite material may vary greatly depending on the processing methods employed to fabricate production parts. Special care needs to be taken in controlling both the materials being procured and how the material is processed once delivered to the fabrication facility. Regulatory requirements in the CSs (namely paragraphs 2x.603 and 2x.605) specify the need to procure and process materials under approved material and process specifications that control the key parameters governing performance. These paragraphs outline a need to protect structures against the degradation possible in service. They also require that the design account for any changes in performance (e.g., environmental and variability effects) permitted by material and process specifications.

a. Material and Process Control.

(1) Specifications covering material, material processing, and fabrication procedures are established to ensure a basis for fabricating reproducible and reliable structure. Material specifications are required to ensure consistent material can be procured. Specifications covering processing procedures should be developed to ensure that repeatable and reliable structure can be manufactured. The means of processing qualification and acceptance tests defined in each material specification should be representative of the expected applicable manufacturing process. The process parameters for fabricating test specimens should match the process parameters to be used in manufacturing actual production parts as closely as possible.

(2) Once the fabrication processes have been established, any changes should undergo additional qualification, including testing of differences before being implemented (see Appendix 3). It is important to establish: (i) processing tolerances, (ii) material handling and storage limits, and (iii) key characteristics of the final product.

(3) Material requirements identified in procurement specifications should be based on the qualification test results for samples produced using the related process specifications. Qualification data must cover all properties important to the control of materials (composites and adhesives) and processes to be used for production of composite Critical Structures. Carefully selected physical, chemical and mechanical qualification tests are used to demonstrate the formulation, stiffness, strength, durability and reliability of materials and processes for aircraft applications. It is recommended that airframe designers and manufacturers work closely with material suppliers to properly define material requirements.

(4) To provide an adequate design database, environmental and long-term durability effects on critical properties of the material systems and associated processes should be established. In addition to testing in an ambient environment, variables should include extreme service temperature and moisture content conditions. Qualification tests for environmental effects and long-term durability are particularly important when evaluating the materials, processes and interface issues associated with structural bonding (see paragraph 6.c for related guidance).

(5) Key characteristics and processing parameters should be specified and monitored for in-process quality control. The overall quality control plan required by the certifying agency should involve all relevant disciplines, i.e., engineering, manufacturing and quality control. A reliable quality control system should be in place to address special engineering requirements that arise in individual parts or areas as a result of potential failure modes, damage tolerance and flaw growth requirements, loadings, inspectability, and local sensitivities to manufacture and assembly.

(6) The discrepancies permitted by the material and process specifications should be substantiated by analysis supported by test evidence, or tests at the coupon, element or sub-component level. For new production methods, repeatable processes should be demonstrated at sufficient structural scale prior to completing all the material and process qualification tests and final development of the associated specifications. This will require integration of the technical issues associated with product design and manufacturing details prior to a large investment in structural tests and analysis correlation. It will also ensure the relevance of quality control procedures defined to control materials and processes as related to the product structural details.

(7) Note that the Agency does not certify materials and processes. However, the materials and processes are included in the approval of the particular aircraft product certification. Appropriate certification credit may be given to products and organisations using the same materials and processes in similar applications subject to substantiation and applicability. In some cases, material and processing information may become part of accepted shared databases used throughout the industry. New users of shared qualification databases must control the associated materials and processes through proper use of the related specifications and demonstrate their understanding by performing equivalency sampling tests for key properties. Note that materials and processes used in European technical standard order (ETSO) articles or authorisations must also be qualified and controlled.

b. Design Considerations for Manufacturing Implementation. Process specifications and manufacturing documentation are needed to control composite fabrication and assembly. The environment and cleanliness of facilities are controlled to a level validated by qualification and proof of structure testing. Raw and ancillary materials are controlled to specification requirements that are consistent with material and process qualifications. Parts fabricated should meet the production tolerances validated in qualification, design data development, and proof of structure tests. Some key fabrication process considerations requiring such control include: (i) material handling and storage, (ii) laminate layup and bagging (or other alternate process steps for non-laminated material forms and advanced processes), (iii) mating part dimensional tolerance control, (iv) part cure (thermal management), (v) machining and assembly, (vi) cured part inspection and handling procedures, and (vii) technician training for specific material, processes, tooling and equipment.

c. Structural Bonding. Bonded structures include multiple interfaces (e.g., composite-to-composite, composite-to-metal, or metal-to-metal), where at least one of the interfaces requires additional surface preparation prior to bonding. The general nature of technical parameters that govern different types of bonded structures are similar. In the case of bonding composite interfaces, a qualified surface preparation of all previously cured substrates is needed to activate their surface for chemical adhesion. All metal interfaces in a bonded structure should also have chemically activated surfaces created by a qualified preparation process. Many technical issues for bonding require cross-functional teams for successful applications. Critical applications require stringent process control and a thorough substantiation of structural integrity.

(1) Most bond failures and problems in service have been traced to invalid qualifications or insufficient quality control of production processes. Physical and chemical tests may be used to control surface preparation, adhesive mixing, viscosity, and cure properties (e.g., density, degree of cure, glass transition temperature). Lap shear stiffness and strength are common mechanical tests for adhesive and bond process qualification. Shear tests do not provide a reliable measure of long-term durability and environmental degradation associated with poor bonding processes (i.e., lack of adhesion). Some type of peel test has proven more reliable for evaluating proper adhesion. Without chemical bonding, the so-called condition of a "weak bond" exists when the bonded joint is either loaded by peel forces or exposed to the environment over a long period of time, or both. Adhesion failures, which indicate the lack of chemical bonding between substrate and adhesive materials, are considered an unacceptable failure mode in all test types. Material or bond process problems that lead to adhesion failures are solved before proceeding with qualification tests.

(2) Process specifications are needed to control adhesive bonding in manufacturing and repair. A "process control mentality", which includes a combination of in-process inspections and tests, has proven to be the most reliable means of ensuring the quality of adhesive bonds. The environment and cleanliness of facilities used for bonding processes are controlled to a level validated by qualification and proof of structure testing. Adhesives and substrate materials are controlled by specifications that are consistent with material and bond process qualifications. The bonding processes used for production and repair meet tolerances validated in qualification, design data development, and proof of structure tests. Some key bond fabrication process considerations requiring such control include: (i) material handling and storage, (ii) bond surface preparation, (iii) mating part dimensional tolerance control, (iv) adhesive application and clamp-up pressure, (v) bond line thickness control, (vi) bonded part cure (thermal management), (vii) cured part inspection and handling procedures, and (vii) bond technician training for specific material, processes, tooling and equipment. Bond surface preparation and subsequent handling controls leading up to the bond assembly and cure must be closely controlled in time and exposure to environment and contamination.

(3) CS 23.573(a) sets the certification specification for primary composite airframe structures, including considerations for damage tolerance, fatigue, and bonded joints. Although this is a small aeroplane rule, the same performance standards are normally expected for large aeroplanes and rotorcraft (via special conditions and CRIs).

(a) For bonded joints, CS 23.573(a)(5) states:

> "*For any bonded joint, the failure of which would result in catastrophic loss of the aeroplane, the limit load capacity must be substantiated by one of the following methods:*
>
> *(i) The maximum disbonds of each bonded joint consistent with the capability to withstand the loads in paragraph (a)(3) of this section must be determined by analysis, tests, or both. Disbonds of each bonded joint greater than this must be prevented by design features; or*
>
> *(ii) Proof testing must be conducted on each production article that will apply the critical limit design load to each critical bonded joint; or*

(iii) Repeatable and reliable non-destructive inspection techniques must be established that ensure the strength of each joint."

(b) These options do not supersede the need for a qualified bonding process and rigorous quality controls for bonded structures. For example, fail safety implied by the first option is not intended to provide adequate safety for the systematic problem of a bad bonding process applied to a fleet of aircraft structures. Instead, it gives fail safety against bonding problems that may occasionally occur over local areas (e.g., insufficient local bond contact pressure or contamination). Performing static proof tests to limit load, which is the second option, may not detect weak bonds requiring environmental exposure and time to degrade bonded joint strength. Finally, the third option is open for future advancement and validation of NDI technology to detect weak bonds, which degrade over time and lead to adhesion failures. Such technology has not been reliably demonstrated at a production scale.

d. Environmental Considerations. Environmental design criteria should be developed that identify the critical environmental exposures, including humidity and temperature, to which the material in the application under evaluation may be exposed. This is not required where existing data demonstrate that no significant environmental effects, including the effects of temperature and moisture, exist for the material system and construction details, within the bounds of environmental exposure being considered.

(1) Experimental evidence should be provided to demonstrate that the material design values or allowables are attained with a high degree of confidence in the appropriate critical environmental exposures to be expected in service. The effect of the service environment on static strength, fatigue and stiffness properties should be determined for the material system through tests; e.g., accelerated environmental tests, or from applicable service data. The maximum moisture content considered is related to that possible during the service life given the details of a given part thickness, moisture diffusion properties and realistic environmental exposures. The effects of environmental cycling (i.e., moisture and temperature) should be evaluated. Existing test data may be used where it can be shown directly applicable to the material system. All accelerated test methods are representative of real-time environmental and load exposure.

(2) Depending on the design configuration, local structural details and selected processes, the effects of residual stresses that depend on environment must be addressed (e.g., differential thermal expansion of attached parts).

e. Protection of Structure. Weathering, abrasion, erosion, ultraviolet radiation, and chemical environment (glycol, hydraulic fluid, fuel, cleaning agents, etc.) may cause deterioration in a composite structure. Suitable protection against and/or consideration of degradation in material properties should be provided for conditions expected in service and demonstrated by test. Where necessary, provide provisions for ventilation and drainage. Isolation layers are needed at the interfaces between some composite and metal materials to avoid corrosion (e.g., glass plies are used to isolate carbon composite layers from aluminium). In addition, qualification of the special fasteners and installation procedures used for parts made from carbon fibre materials need to address the galvanic corrosion issues. Early carbon fibre applications using traditional aluminium rivets and bolts had service problems.

f. Design Values. Data used to derive design values must be obtained from stable and repeatable material that conforms to mature material and production process specifications. This will ensure that the permitted variability of the production materials is captured in the statistical analysis used to derive the design values. Design values derived too early in the material's development stage, before raw material and composite part production processes have matured, may not satisfy the intent of the associated rules. Laminated material system design values should be established on the laminate level by either test of the laminate or by test of the lamina in conjunction with a test validated analytical method. Similarly, design values for non-laminated material forms and advanced composite processes must be established at the scale that best represents the material as it appears in the part or by tests of material substructure in conjunction with a test validated analytical method.

g. **Structural Details.** For a specific structural configuration of an individual component (point design), design values may be established which include the effects of appropriate design features (holes, joints, etc.). In the absence of specific metrics for composite structural damage states, such as caused by foreign impact damage threats, testing will be needed to characterise residual strength, including the structural effects of critical damage location and combined loads. Different levels of impact damage are generally accommodated by limiting the design strain levels for ultimate and limit combined load design criteria.

7. PROOF OF STRUCTURE – STATIC.

The structural static strength substantiation of a composite design should consider all critical load cases and associated failure modes. It should also include effects of environment (including residual stresses induced during the fabrication process), material and process variability, and defects or service damage that are not detectable or allowed by the quality control, manufacturing acceptance criteria, or maintenance documents of the end product. The static strength of the composite design should be demonstrated through a programme of component ultimate load tests in the appropriate environment, unless experience with similar designs, material systems and loadings is available to demonstrate the adequacy of the analysis supported by sub-component, element and coupon tests, or component tests to accepted lower load levels. The necessary experience to validate an analysis should include previous component ultimate load tests with similar designs, material systems, and load cases.

a. The effects of repeated loading and environmental exposure which may result in material property degradation should be addressed in the static strength evaluation. This can be shown by analysis supported by test evidence, by tests at the coupon, element or sub-component level, as appropriate, or alternatively by relevant existing data. Earlier discussions in this AMC address the effects of environment on material properties (paragraph 6.d) and protection of structure (paragraph 6.e). For critical loading conditions, three approaches to account for prior repeated loading and/or environmental exposure in the full scale static test exist.

(1) In the first approach, the full scale static test should be conducted on structure with prior repeated loading and conditioned to simulate the environmental exposure and then tested in that environment.

(2) The second approach relies upon coupon, element and sub-component test data to assess the possible degradation of static strength after application of repeated loading and environmental exposure. The degradation characterised by these tests should then be accounted for in the full scale static strength demonstration test (e.g., overload factors), or in analysis of these results (e.g., showing a positive margin of safety with design values that include the degrading effects of environment and repeated load).

(3) In practice, aspects of the first two approaches may be combined to obtain the desired result (e.g., a full scale static test may be performed at maximum operating temperature with a load factor to account for moisture absorbed over the aircraft structure’s life).

b. The strength of the composite structure should be reliably established, incrementally, through a programme of analysis and a series of tests conducted using specimens of varying levels of complexity. Often referred to in industry as the "building block" approach, these tests and analyses at the coupon, element, details and sub-component levels can be used to address the issues of variability, environment, structural discontinuity (e.g., joints, cut-outs or other stress risers), damage, manufacturing defects, and design or process-specific details. Typically, testing progresses from simple specimens to more complex elements and details over time. This approach allows the data collected for sufficient analysis correlation and the necessary replicates to quantify variations occurring at the larger structural scales to be economically obtained. The lessons learned from initial tests also help avoid early failures in more complex full scale tests, which are more costly to conduct and often occur later in a certification programme schedule.

(1) Figures 1 and 2 provide a conceptual schematic of tests typically included in the building block approach for a fixed wing and tail rotor blade structures, respectively. The large quantity of tests needed to provide a statistical basis comes from the lowest levels (coupons and elements) and the performance of structural details are validated in a lesser number of sub-component and component tests. Appropriate analysis validation at the detail and sub-component testing levels should demonstrate the confidence to predict local strains and ensure repeatable failure modes as required to meet the static strength rules for a reliable design. Additional statistical considerations (e.g., repetitive point design testing and/or component overload factors to cover material and process variability) will be needed when analysis validation is not achieved. The static strength substantiation programme should also consider all critical loading conditions for all Critical Structure. This includes an assessment of residual strength and stiffness requirements after a predetermined length of service, which takes into account damage and other degradation due to the service period.

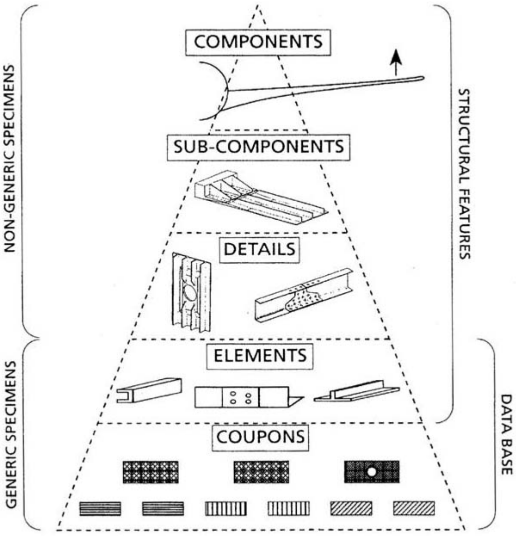

Figure 1 - Schematic diagram of building block tests for a fixed wing.

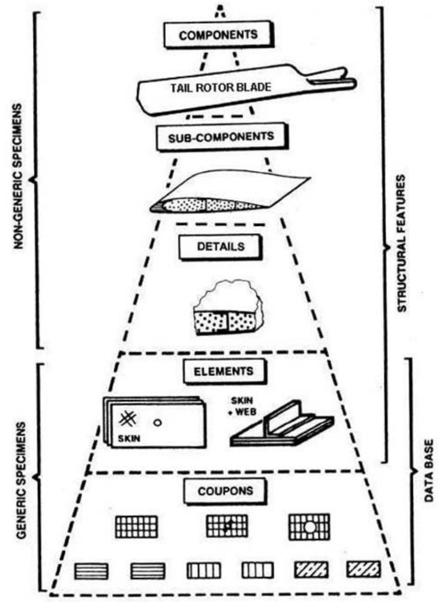

Figure 2 - Schematic diagram of building block tests for a tail rotor blade.

(2) Successful static strength substantiation of composite structures has traditionally depended on proper consideration of stress concentrations (e.g., notch sensitivity of details and impact damage), competing failure modes and out-of-plane loads. Depending on the complexity of co-cured, bonded and mechanically assembled structure, some of these factors can be difficult to analyse for combined loading conditions. A complete building block approach to composite structural substantiation addresses most critical structural issues in test articles with increasing levels of complexity such that many areas of reliable performance can be demonstrated prior to the component tests (e.g., effects of stress risers and impact damage). The details and sub-component testing should yield the necessary information to establish semi-empirical failure criteria and account for impact damage in assembled composite structures. When using the building block approach, the critical load cases and associated failure modes would be identified for component tests using the analytical methods, which are supported by test validation. Component tests are needed to provide the final accounting for combined loads and complex load paths, which include some out-of-plane effects.

c. The component static test may be performed in an ambient atmosphere if the effects of the environment are reliably predicted by building block tests and are accounted for in the static test or in the analysis of the results of the static test.

d. The static test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure including defects consistent with the limits established by manufacturing acceptance criteria.

e. The material and processing variability of the composite structure should be considered in the static strength substantiation. This is primarily achieved by establishing sufficient process and quality controls to manufacture structure and reliably substantiate the required strength by test and analysis. The scatter in strength properties due to variability in materials and processes are characterised by proper allowables or design values, which are derived in compliance with CS 2x.613. When the detail, sub-component and component tests show that local stresses are adequately predicted and positive margins of safety exist using a validated analysis everywhere on the structure, then proof of static strength is said to be substantiated using analysis supported by test evidence. Alternatively, in the absence of sufficient building block test data and analysis validation, overloads are needed in the component test to gain proof of static strength for the structure using an approach referred to as substantiated by tests. The overload factors applied in this case need to be substantiated either through tests or past experience and must account for the expected material and process variation.

f. It should be shown that impact damage that can be expected from manufacturing and service, but not more than the established threshold of detectability for the selected inspection procedure, will not reduce the structural strength below ultimate load capability. This can be shown by analysis supported by test evidence, or by a combination of tests at the coupon, element, sub-component and component levels. The realistic test assessment of impact damage requires proper consideration of the structural details and boundary conditions. Selection of impact sites for static strength substantiation should consider the magnitude of local loads, competing failure modes, structural attachments (e.g., bonded details), and the ability to inspect a location. The size and shape of impactors used for static strength substantiation should be consistent with likely impact damage scenarios that may go undetected for the life of an aircraft.

g. Any change to material and/or process will need to be assessed and significant material and process changes may require additional static strength substantiation (see Appendix 3).

8. PROOF OF STRUCTURE – FATIGUE AND DAMAGE TOLERANCE.

The evaluation of composite structure should be based on the applicable certification specifications identified in the type-certification basis. Such evaluation must show that catastrophic failure due to fatigue, environmental effects, manufacturing defects, or accidental damage will be avoided throughout the operational life of the aircraft. The nature and extent of analysis or tests on complete structures and/or portions of the primary structure will depend upon applicable previous fatigue/damage tolerant designs, construction, tests, and service experience on similar structures. In the absence of experience with similar designs, Agency-approved structural development tests of components, sub-components, and elements should be performed (following the same principles discussed in paragraph 7.b and Appendix 3). The following considerations are unique to the use of composite material systems and provide guidance for the method of substantiation selected by the applicant. When establishing details for the damage tolerance and fatigue evaluation, attention should be given to a thorough damage threat assessment, geometry, inspectability, good design practice, and the types of damage/degradation of the structure under consideration.

- Composite damage tolerance and fatigue performance is strongly dependent on structural design details (e.g., skin laminate stacking sequence, stringer or frame spacing, stiffening element attachment details, damage arrestment features, and structural redundancy).
- Composite damage tolerance and fatigue evaluations require substantiation in component tests unless experience with similar designs, material systems and loadings is available to demonstrate the adequacy of the analysis supported by coupons, elements and sub-component tests.
- Final static strength, fatigue and damage tolerance substantiation may be gained in testing a single component test article if sufficient building block test evidence exists to ensure the specific sequence of loading is representative of that possible in service or is a conservative evaluation.
- High loads are needed to practically demonstrate the environmental capability and reliable static strength, fatigue and damage tolerance of composite aircraft structure in a limited number of component tests. As a result, metal structures present in the test article generally require additional consideration and testing.

a. Damage Tolerance Evaluation.

(1) Damage tolerance evaluation starts with identification of structure whose failure would reduce the structural integrity of the aircraft. A damage threat assessment must be performed for the structure to determine possible locations, types and sizes of damage considering fatigue, environmental effects, intrinsic flaws, and foreign object impact or other accidental damage (including discrete source) that may occur during manufacture, operation or maintenance.

(a) There currently are very few industry standards that outline the critical damage threats for particular composite structural applications with enough detail to establish the necessary design criteria or test and analysis protocol for complete damage tolerance evaluation. In the absence of standards, it is the responsibility of individual applicants to perform the necessary development tasks to establish such data in support of product substantiation. Some factors to consider in development of a damage threat assessment for a particular composite structure include part function, location on the aircraft, past service data, accidental damage threats, environmental exposure, impact damage resistance, durability of assembled structural details (e.g., long-term wear-out of bolted and bonded joints), adjacent system interface (e.g., potential overheating or other threats associated with system failure), and anomalous service or maintenance handling events that can overload or damage the part. As related to the damage threat assessment and maintenance procedures for a given structure, the damage tolerance capability and ability to inspect for known damage threats should be developed.

(b) Foreign object impact is a concern for most composite structures, requiring attention in the damage threat assessment. This is needed to identify impact damage severity and detectability for design and maintenance. It should include any available damage data collected from service plus an impact survey. An impact survey consists of impact tests performed with representative structure, which is subjected to boundary conditions characteristic of the real structure. Many different impact scenarios and locations should be considered in the survey, which has a goal of identifying the most critical impacts possible (i.e., those causing the most serious damage but are least detectable). When simulating accidental impact damage at representative energy levels, blunt or sharp impactors of different sizes and shapes should be selected to cause the most critical and least detectable damage, according to the load conditions (e.g. tension, compression or shear). Until sufficient service experience exists to make good engineering judgments on energy and impactor variables, impact surveys should consider a wide range of conceivable impacts, including runway or ground debris, hail, tool drops, and vehicle collisions. This consideration is important to the assumptions needed for use of probabilistic damage threat assessments in defining design criteria, inspection methods and repeat inspection intervals for maintenance. Service data collected over time, can better define impact surveys and design criteria for subsequent products, as well as establish more rational inspection intervals and maintenance practice. In review of such information, it should be realized that the most severe and critical impact damages, which are still possible, may not be part of the service database.

(c) Once a damage threat assessment is completed, various damage types can be classified into five categories of damage as described below (see Figure 3).

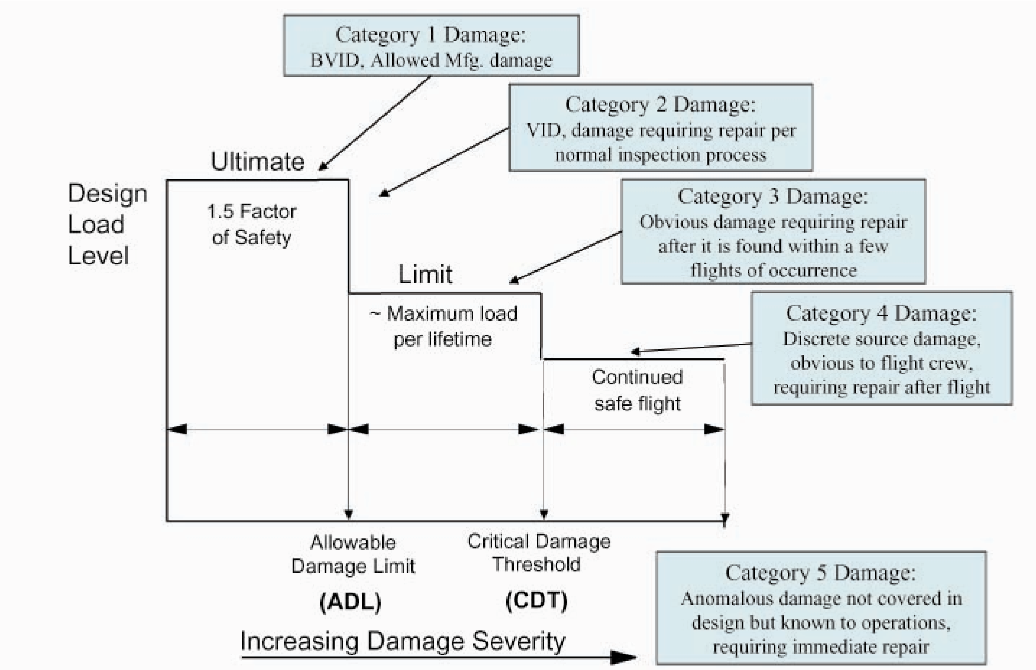

Figure 3 - Schematic diagram showing design load levels versus categories of damage severity.

Category 1: Allowable damage that may go undetected by scheduled or directed field inspection or allowable manufacturing defects. Structural substantiation for Category 1 damage includes demonstration of a reliable service life, while retaining ultimate load capability. By definition, such damage is subjected to the requirements and guidance associated with paragraph 6 of this advisory circular. Some examples of Category 1 damage include Barely visible impact damage (BVID) and allowable defects caused in manufacturing or service (e.g., small delamination, porosity, small scratches, gouges, and minor environmental damage) that have substantiation data showing ultimate load is retained for the life of an aircraft structure.

Category 2: Damage that can be reliably detected by scheduled or directed field inspections performed at specified intervals. Structural substantiation for Category 2 damage includes demonstration of a reliable inspection method and interval while retaining loads above limit load capability. The residual strength for a given Category 2 damage may depend on the chosen inspection interval and method of inspection. Some examples of Category 2 damage include visible impact damage, VID (ranging in size from small to large), deep gouges or scratches, manufacturing mistakes not evident in the factory, detectable delamination or debonding and major local heat or environmental degradation that will sustain sufficient residual strength until found. This type of damage should not grow or, if slow or arrested growth occurs, the level of residual strength retained for the inspection interval is sufficiently above limit load capability.

Category 3: Damage that can be reliably detected within a few flights of occurrence by operations or ramp maintenance personnel without special skills in composite inspection. Such damage must be in a location such that it is obvious by clearly visible evidence or cause other indications of potential damage that becomes obvious in a short time interval because of loss of the part form, fit or function. Both indications of significant damage warrant an expanded inspection to identify the full extent of damage to the part and surrounding structural areas. In practice, structural design features may be needed to provide sufficient large damage capability to ensure limit or near limit load is maintained with easily detectable, Category 3 damage. Structural substantiation for Category 3 damage includes demonstration of a reliable and quick detection, while retaining limit or near limit load capability. The primary difference between Category 2 and 3 damages are the demonstration of large damage capability at limit or near limit load for the latter after a service interval of time, which is much shorter than the former. The residual strength demonstration for Category 3 damage may be dependent on the reliable short time detection interval. Some examples of Category 3 damage include large VID or other obvious damage that will be caught during walk-around inspection or during the normal course of operations (e.g., fuel leaks, system malfunctions or cabin noise).

Category 4: Discrete source damage from a known incident such that flight manoeuvres are limited. Structural substantiation for Category 4 damage includes a demonstration of residual strength for "Get-Home" loads specified in the regulations. Some examples of Category 4 damage include rotor burst, significant bird strikes, exploding gear tires, and severe in-flight hail.

Category 5: Severe damage created by anomalous ground or flight events, which is not covered by design criteria or structural substantiation procedures. This damage is in the current guidance to ensure sufficient designed-in damage resistance and field knowledge, which outlines the Category 5 events that are self-evident and require conditional inspections. As a result, the engineers responsible for composite aircraft structure design together with the Agency need to work with maintenance organisations in making operations personnel aware of possible damage from Category 5 events and the essential need for immediate reporting to responsible maintenance personnel. An interface is needed with engineering to properly define a suitable inspection based on available information from the anomalous event. Such action will facilitate the damage characterization needed prior to repair. Some examples of Category 5 damage include severe service vehicle collisions with aircraft, anomalous flight overload conditions, abnormally hard landings, maintenance jacking errors, and loss of aircraft parts in flight, including possible subsequent high-energy, wide-area (blunt) impact with adjacent structure. It is realized that some Category 5 damage scenarios will not have clearly visual indications of damage, particularly in composite structures. However, there should be knowledge of other evidence from the related events that ensure safety is protected, starting with a complete report of possible damage by operations.

(d) The five categories of damage will be used as examples in subsequent discussion in this paragraph and in paragraphs 9 and 10. Note that Category 2, 3, 4 and 5 damages all have associated repair scenarios.

(2) Structure details, elements, and sub-components of Critical Structure should be tested under repeated loads to define the sensitivity of the structure to damage growth. This testing can form the basis for validating a no-growth approach to the damage tolerance requirements. The testing should assess the effect of the environment on the flaw growth characteristics and the no-growth validation. The environment used should be appropriate to the expected service usage. Residual stresses will develop at the interfaces between composite and metal structural elements in a design due to differences in thermal expansion. This component of stress will depend on the service temperature during repeated load cycling and is considered in the damage tolerance evaluation. Inspection intervals should be established, considering both the likelihood of a particular damage and the residual strength capability associated with this damage. The intent of this is to assure that structure is not exposed to an excessive period of time with residual strength less than ultimate, providing a lower safety level than in the typical slow growth situation, as illustrated in the Figure 4. Conservative assumptions for capability with large damage sizes that would be detected within a few flights may be needed when probabilistic data on the likelihood of given damage sizes does not exist. Once the damage is detected, the component is either repaired to restore ultimate load capability or replaced.

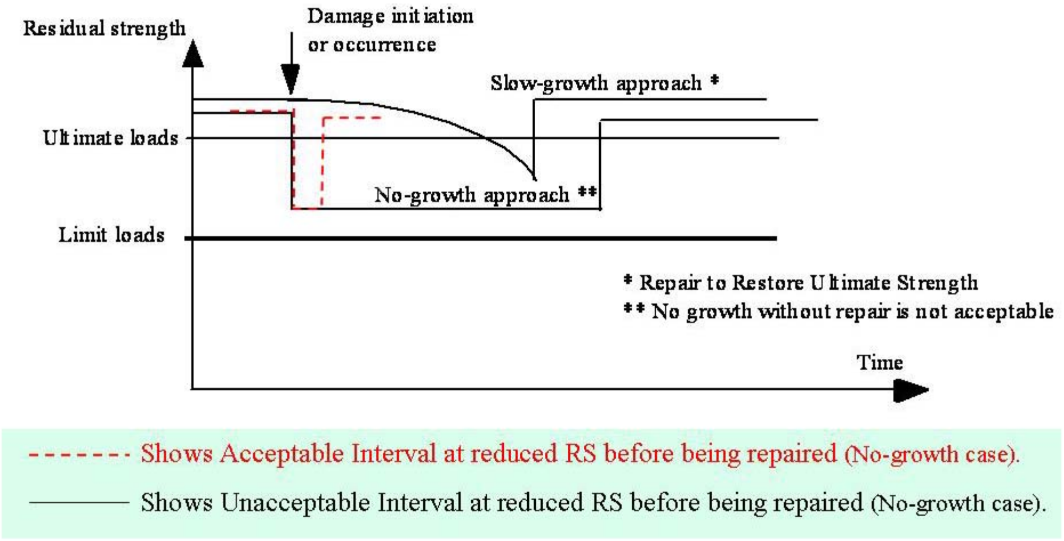

Figure 4 - Schematic diagram of residual strength illustrating that significant accidental damage with "no-growth" should not be left in the structure without repair for too long of time.

(a) The traditional slow growth approach may be appropriate for certain damage types found in composites if the growth rate can be shown to be slow, stable and predictable. Slow growth characterization should yield conservative and reliable results. As part of the slow growth approach, an inspection programme should be developed consisting of the frequency, extent, and methods of inspection for inclusion in the maintenance plan. Inspection intervals should be established such that the damage will have a very high probability of detection between the time it becomes initially inspectable and the time at which the extent of the damage reduces the residual static strength to limit load (considered as ultimate), including the effects of environment. For any damage size that reduces the load capability below ultimate, the component is either repaired to restore ultimate load capability or replaced. Should functional impairment (such as unacceptable loss of stiffness) occur before the damage becomes otherwise critical, part repair or replacement will also be necessary.

(b) Another approach involving growth may be appropriate for certain damage types and design features adopted for composites if the growth can reliably be shown to be predictable and arrested before it becomes critical. Figure 5 shows schematic diagrams for all three damage growth approaches applied to composite structure. The Arrested Growth Approach is applicable when the damage growth is mechanically arrested or terminated before becoming critical (residual static strength reduced to limit load), as illustrated in Figure 5. Arrested growth may occur due to design features such as a geometry change, reinforcement, thickness change, or a structural joint. This approach is appropriate for damage growth that is inspectable and found to be reliably arrested, including all appropriate dynamic effects. Structural details, elements, and sub-components of Critical Structure, components or full-scale structures, should be tested under repeated loads for validating an Arrested Growth Approach. As was the case for a "no-growth" approach to damage tolerance, inspection intervals should be established, considering the residual strength capability associated with the arrested growth damage size (see the dashed lines added to Figure 5 to conceptually show inspection intervals consistent with the slow growth basis). Again, this is intended to ensure that the structure does not remain in a damaged condition with residual strength capability close to limit load for long periods of time before repair. For any damage size that reduces load capability below ultimate, the component is either repaired to restore ultimate load capability or replaced.

(c) The repeated loading should be representative of anticipated service usage. The repeated load testing should include damage levels (including impact damage) typical of those that may occur during fabrication, assembly, and in-service, consistent with the inspection techniques employed. The damage tolerance test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure.

(3) The extent of initially detectable damage should be established and be consistent with the inspection techniques employed during manufacture and in service. This information will naturally establish the transition between Category 1 and 2 damage types (i.e., inspection methods used by trained inspectors in scheduled maintenance). For damage that is clearly detectable to an extent that it will likely be found before scheduled maintenance (i.e., allowing classification as Category 3 damage), detection over shorter intervals and by untrained personnel may be permitted. Flaw/damage growth data should be obtained by repeated load cycling of intrinsic flaws or mechanically introduced damage. The number of cycles applied to validate a no-growth concept should be statistically significant, and may be determined by load and/or life considerations and a function of damage size. The growth or no growth evaluation should be performed by analysis supported by test evidence or by tests at the coupon, element, or sub-component level.

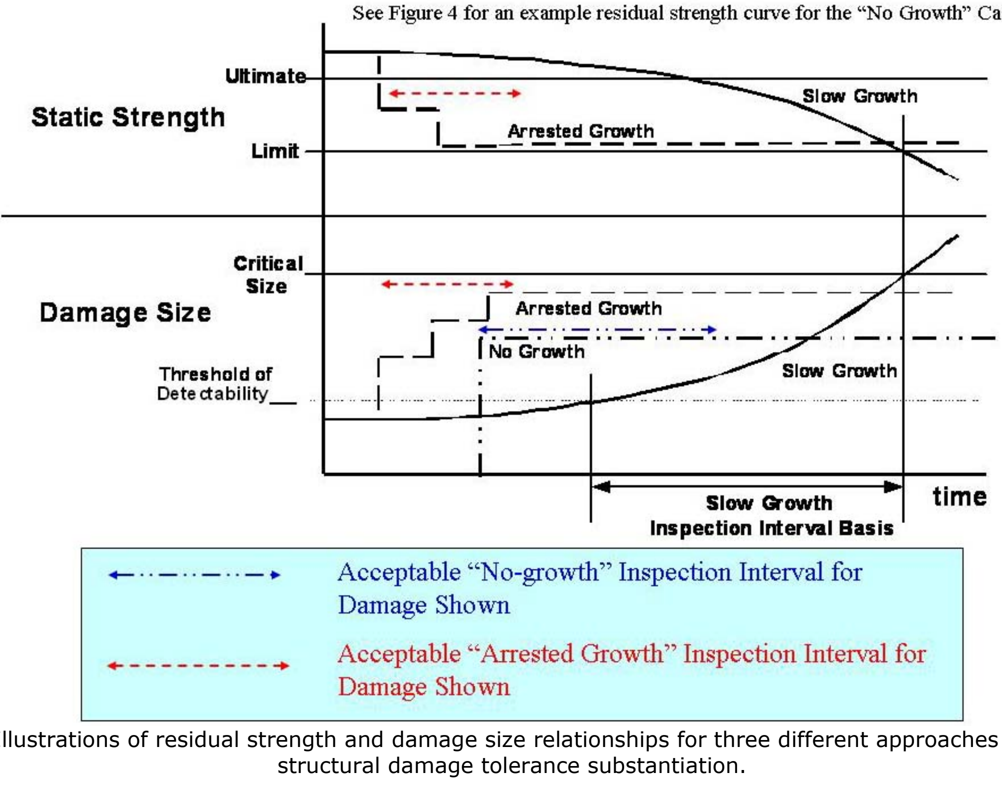

Figure 5 - Illustrations of residual strength and damage size relationships for three different approaches to composite structural damage tolerance substantiation.

(4) The extent of damage for residual strength assessments should be established, including considerations for the probability of detection using selected field inspection procedures. The first four categories of damage should be considered based on the damage threat assessment. Residual strength evaluation by component or sub-component testing or by analysis supported by test evidence should be performed considering that damage. The evaluation should demonstrate that the residual strength of the structure will reliably be equal to or greater than the strength required for the specified design loads (considered as ultimate), including environmental effects. The statistical significance of reliable sub-component and detail residual strength assessments may include conservative methods and engineering judgment. It should be shown that stiffness properties have not changed beyond acceptable levels.

(a) For the no-growth approach, residual strength testing should be performed after repeated load cycling. All probabilistic analyses applied for residual strength assessments should properly account for the complex nature of damage defined from a thorough damage threat assessment (conservative damage metrics are permitted in such analyses assuming sufficient test data on repeated load and environmental exposure exists).

(b) Composite designs should afford the same level of fail-safe, multiple load path structure assurance as conventional metals design. Such is also the expectation in justifying the use of allowables with a statistical basis of 90 percent probability with 95 percent confidence.

(c) Some special residual strength considerations for bonded structure are given in paragraph 6.c.(3).

(5) The repeated load spectrum developed for fatigue testing and analysis purposes should be representative of the anticipated service usage. Low amplitude load levels that can be shown not to contribute to damage growth may be omitted (truncated). Reducing maximum load levels (clipping) is generally not accepted. Variability in repeated load behaviour should be covered by appropriate load enhancement or life scatter factors and these factors should take into account the number of specimens tested. The use of such factors to demonstrate reliability in component tests should be consistent with the fatigue and damage tolerance behaviour characterised for the materials, processes and other design details of the structure in building block tests.

(6) An inspection programme should be developed consisting of frequency, extent, and methods of inspection for inclusion in the maintenance plan. Inspection intervals should be established such that the damage will be detected between the time it initially becomes detectable and the time at which the extent of damage reaches the limits for required residual strength capability.

(a) For the case of no-growth design concept, inspection intervals should be established as part of the maintenance programme. In selecting such intervals that residual strength level associated with the assumed damages should be considered. This point was illustrated in Figures 4 and 5. Note that an acceptable inspection interval for the larger damages shown for the "no-growth" and "arrested growth" options in Figures 4 and 5 was conceptually shown as related to an acceptable slow growth basis in terms of the residual strength and time below ultimate load before damage was detected and repaired. Data on the probability of occurrence for different damage sizes also helps define an inspection interval.

(b) A thorough composite damage threat assessment and the separation of different damage sizes into categories, each with associated detection methods, supports programmes using a rigorous damage tolerance assessment to avoid conservative design criteria with very large damage assumptions. In such cases, Category 2 damage types will require the structural substantiation of well-specified and reliable inspection methods applied by trained inspectors at scheduled maintenance intervals (by default, Category 1 damage is at the threshold of this evaluation). Those damages classified as Category 3 may take advantage of shorter service time intervals provided sufficient structural substantiation exists with demonstrated proof that there will be early detection by untrained ramp maintenance or operations personnel. By definition, Category 4 damage will require residual strength substantiation to levels that complete a flight with limited manoeuvres based on the associated regulatory loads. Due to the nature of service events leading to Category 4 damage, suitable inspections will need to be defined to evaluate the full extent of damage, prior to subsequent aircraft repair and return to service. By definition, Category 5 damages do not have associated damage tolerance design criteria or related structural substantiation tasks. Category 5 damage will require suitable inspections based on engineering assessment of the anomalous service event, and appropriate structural repair and/or part replacement, prior to the aircraft re-entering service.

(7) The structure should be able to withstand static loads (considered as ultimate loads) which are reasonably expected during a completion of the flight on which damage resulting from obvious discrete sources occur (i.e., uncontained engine failures, etc.). The extent of damage should be based on a rational assessment of service mission and potential damage relating to each discrete source. Structural substantiation will be needed for the most critical Category 4 damage as related to the associated load cases. Those Category 4 damages that will not require specific residual strength assessments for the associated get home loads because they have high margins (e.g., severe in-flight hail) will likely still require suitable inspections because their detectability may not be consistent with the substantiations validated for Category 2 damage types.

(8) The effects of temperature, humidity, and other environmental or time-related aging factors which may result in material property degradation should be addressed in the damage tolerance evaluation. Unless tested in the environment, appropriate environmental overload factors for the static and fatigue test articles should be derived and applied in the evaluation.

b. Fatigue Evaluation. Fatigue substantiation should be accomplished by component fatigue tests or by analysis supported by test evidence, accounting for the effects of the appropriate environment. The test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structures. Sufficient component, sub-component, element or coupon tests should be performed to establish the fatigue scatter and the environmental effects. Component, sub-component, and/or element tests may be used to evaluate the fatigue response of structure with impact damage levels typical of those that may occur during fabrication, assembly, and in service, consistent with the inspection procedures employed. Other allowed manufacturing and service defects, which would exist for the life of the structure, should also be included in fatigue testing. It should be demonstrated during the fatigue tests that the stiffness properties have not changed beyond acceptable levels. Replacement lives should be established based on the test results. By definition, Category 1 damage is subjected to fatigue evaluation and expected to retain ultimate load capability for the life of the aircraft structure.

c. Combined Damage Tolerance and Fatigue Evaluation. Generally, it is appropriate for a given structure to establish both an inspection programme and demonstrate a service life to cover all detectable and non-detectable damage, respectively, which is anticipated for the intended aircraft usage. As in metals, there is a limit on the useful service life of composite airframe structures, based on available data and analyses. All extensions in structural life should include evidence from component repeated load testing, fleet leader programmes (including NDI and destructive tear-down inspections), and appropriate statistical assessments of accidental damage and environmental service data considerations.

9. PROOF OF STRUCTURE – FLUTTER AND OTHER AEROELASTIC INSTABILITIES.

The aeroelastic evaluations including flutter, control reversal, divergence, and any undue loss of stability and control as a result of structural loading and resulting deformation are required.

Flutter and other aeroelastic instabilities must be avoided through design, quality control, maintenance and careful attention to the neighbouring systems interface.

a. The evaluation of composite structure needs to account for the effects of repeated loading, environmental exposure and service damage scenarios (e.g., large Category 2, 3 or 4 damage, and potential mass increase for sandwich panel water ingression) on critical properties such as stiffness, mass and damping. Note that some control surfaces exposed to large damage retain adequate residual strength margins, but the potential loss of stiffness may adversely affect flutter and other aeroelastic characteristics. This is particularly important for control surfaces that are relatively fragile and prone to accidental damage and environmental degradation. Other factors such as the weight or stiffness changes due to repair, manufacturing flaws and multiple layers of paint need to be evaluated. Control surface clearances may also be an issue that can change with alterations, damage and repair. There may also be issues associated with the proximity of high temperature heat sources near structural components (e.g., empennage structure in the path of jet engine exhaust streams). These effects may be determined by analysis supported by test evidence, or by tests at the coupon, element or sub-component level.

10. CONTINUED AIRWORTHINESS.

The maintenance and repair of composite aircraft structure shall meet all general, design and fabrication, static strength, fatigue/damage tolerance, flutter, and other considerations covered by this advisory circular as appropriate for the particular type of structure and its application.

a. **Design for Maintenance**. Composite aircraft structure should be designed for inspection and repair access in a field maintenance environment. The inspection and repair methods applied for structural details should recognize the special documentation and training needed for critical damage types that are difficult to detect, characterize and repair. The inspection intervals and life limits for any structural details and levels of damage that preclude repair must be clearly documented in the airworthiness limitations section of instructions for continued airworthiness.

b. **Maintenance Practices**. Maintenance manuals, developed by manufacturers should include appropriate inspection, maintenance and repair procedures for composite structures, including jacking, disassembly, handling, part drying methods and repainting instructions (including restrictions for paint colours that increase structural temperatures). Special equipment, repair materials, ancillary materials, tooling, processing procedures and other information needed for inspection or repair of a given part should be identified since standard field practices, which have been substantiated for different aircraft types and models, are not common.

(1) Damage Detection.

(a) Procedures used for damage detection must be shown to be reliable and capable of detecting degradation in structural integrity below ultimate load capability. These procedures must be documented in the appropriate sections of the instructions for continued airworthiness. This should be substantiated in static strength, environmental resistance, fatigue and damage tolerance efforts as outlined in paragraphs 6, 7 and 8. Substantiated detection procedures will be needed for all damage types identified by the threat assessment, including a wide range of foreign object impact threats, manufacturing defects and degradation caused by overheating. Degradation in surface layers (e.g., paints and coatings) that provide structural protection against ultraviolet exposure must be detected. Any degradation to the lightning strike protection system that affects structural integrity, fuel tank safety and electrical systems must also be detected.

(b) Visual inspection is the predominant damage detection method used in the field and should be performed under prescribed lighting conditions. Visual inspection procedures should account for access, time relaxation in impact damage dent depth, and the colour, finish and cleanliness of part surfaces.

(2) Inspection. Visual indications of damage, which are often used for composite damage detection, provide limited details on the hidden parts of damage that requires further investigation. As a result, additional inspection procedures used for complete composite damage characterization will generally be different than those used for initial damage detection and need to be well documented. Non-destructive inspection performed prior to repair and destructive processing steps performed during repair must be shown to locate and determine the full extent of the damage. In-process controls of repair quality and post-repair inspection methods must be shown to be reliable and capable of providing engineers with the data to determine degradation in structural integrity below ultimate load capability caused by the process itself. In the case of processing defects that cannot be reliably detected following completion of the repair (e.g., weak bonds), repair design features and limits that ensure sufficient damage tolerance until the damage can be reliably detected will be needed, as is the case for base composite structures.

(3) Repair. All bolted and bonded repair design and processing procedures applied for a given structure shall be substantiated to meet the appropriate requirements. Of particular safety concern are the issues associated with bond material compatibilities, bond surface preparation (including drying, cleaning and chemical activation), cure thermal management, composite machining, special composite fasteners and installation techniques, and the associated in-process control procedures. The surface layers (e.g., paints and coatings) that provide structural protection against ultraviolet exposure, structural temperatures and the lightning strike protection system must also be properly repaired. Documentation on all repairs must be added to the maintenance records for the specific part number. This information supports future maintenance damage disposition and repair activities performed on the same part. Service difficulties, damage and degradation occurring to composite parts in service should be reported back to the design approval holder to aid in continuous updates of damage threat assessments to support future design detail and process improvements. Such information will also support future design criteria, analysis and test database developments.

c. Substantiation of Repair.

(1) When repair procedures are provided in Agency approved documents or the maintenance manual, it should be demonstrated by analysis and/or test that the method and techniques of repair will restore the structure to an airworthy condition. Repairable damage limits (RDL), which outline the details for damage to structural components that may be repaired based on existing data, must be clearly defined and documented. The RDL may be linked with specified levels of repair skills for maintenance personnel and repair conditions in the field. There will be likely differences in the RDL for parts that can be removed from the aircraft for repair and those requiring repair on the aircraft. In some cases, larger RDL may also be substantiated for personnel with additional, special skills to execute the repair. Allowable damage limits (ADL), which do not require repair, must also be clearly defined and documented. Both RDL and ADL must be based on sufficient analysis and test data to meet the appropriate structural substantiation requirements and other considerations outlined in this advisory circular. Additional substantiation data will generally be needed for damage types and sizes not previously considered in design development. Category 3, 4 and 5 damage types will generally also require special instructions for field repair and the associated quality control. Bonded repair to significant levels of damage is subjected to the same structural bonding considerations as the base design (see paragraph 6.c).

(2) Operators and maintenance repair organisations (MRO) wishing to complete major repairs, or alterations outside the scope of approved repair documentation should consult the design approval holder because extensive design and process substantiation is needed to ensure the airworthiness of a certificated structure.

d. Damage Detection, Inspection and Repair Competency.

(1) All technicians, inspectors and engineers involved in damage disposition and repair should have the necessary skills to perform their supporting maintenance tasks on a specific composite structural part. The continuous demonstration of acquired skills goes beyond initial training (e.g., similar to a welder qualification). The repair design, inspection methods, and repair procedures used will require approved structural substantiation data for the particular composite part. Society of Automotive Engineers International (SAE) Aerospace Information Report (AIR) 5719 outlines training for an awareness of the safety issues for composite maintenance and repair. Additional training for specific skill-building will be needed to execute particular engineering, inspection and repair tasks.

(2) Pilots, ramp maintenance and other operations personnel that service aircraft should be trained to immediately report anomalous ramp incidents and flight events that may potentially cause serious damage to composite aircraft structures. In particular, immediate reporting is needed for those service events that are outside the scope of the damage tolerance substantiation and standard maintenance practices for a given structure. The immediate detection of Category 4 and 5 damages are dependent on the proper reaction of personnel that operate and service the aircraft. .

11. ADDITIONAL CONSIDERATIONS.

a. Crashworthiness.

(1) The "crashworthiness" of the aircraft is dominated by the impact response characteristics of the fuselage. Regulations, in general, evolve based on either experience gained through incidents and accidents of existing aircraft or in anticipation of safety issues raised by new designs. In the case of crashworthiness, regulations have evolved as experience has been gained during actual aircraft operations. For example, emergency load factors and passenger seat loads have been established to reflect dynamic conditions observed from fleet experience and from controlled FAA and industry research. Fleet experience has not demonstrated a need to have an aircraft level crashworthiness standard. As a result, the regulations reflect the capabilities of traditional aluminium aircraft structure under survivable crash conditions. This approach was satisfactory as aircraft have continued to be designed using traditional construction methods. With the advent of composite fuselage structure, this historical approach may no longer be sufficient to maintain the same level of protection for the passengers as provided by similar metallic designs.

(2) Airframe design should assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable crash impact conditions. A composite design should account for unique behaviour and structural characteristics, including repairs or alterations, as compared with conventional metal airframe designs that have been shown to meet current crashworthiness requirements. Structural evaluation may be done by test or analysis supported by test evidence. Service experience may also support substantiation.

(3) The crash dynamics of an aircraft and the associated energy absorption are difficult to model and fully define representative tests with respect to structural requirements. ***Each aircraft product type (i.e., Large aeroplane, small aeroplane, rotorcraft) has unique regulations governing the crashworthiness of particular aircraft***

structures. The regulations and guidance associated with each product type should be used accordingly. The regulations for large aeroplane and rotorcraft address some issues that go beyond those required of small aeroplanes. Additionally, any dynamic seat modelling efforts should take into account related guidance for the applicable product type. The aircraft size also distinguishes some of the key issues as related to passenger egress following a survivable crash.

(4) The impact response of a composite transport fuselage structure must be evaluated to ensure that survivable crashworthiness characteristics are not significantly different from those of a similar-sized aircraft fabricated from metallic materials. Impact loads and resultant structural deformation of the supporting airframe and floor structures must be evaluated. Four main criteria areas should be considered in making such an evaluation.

- Occupants must be protected during the impact event from release of items of mass (e.g., overhead bins).
- The emergency egress paths must remain following a survivable crash.
- The acceleration and loads experienced by occupants during a survivable crash must not exceed critical thresholds.
- A survivable volume of occupant space must be retained following the impact event.

(5) The criticality of each of these four criteria will depend on the particular crash conditions. For example, the loads and accelerations experienced by passengers may be higher at lower impact velocities where structural failures have not started to occur. As a result, validated analyses may be needed to practically cover all the crashworthiness criteria for transport fuselage.

(6) Existing large aeroplane requirements also require that fuel tank structural integrity be addressed during a survivable crash impact event as related to fire safety (also see paragraph 11.b). Again, the benchmark for evaluation of composite structures integral to the fuel tank is the performance of similar-sized aeroplane structures fabricated from metallic materials. As related to crashworthiness, composite fuel tank structure must not fail or deform to the extent that fire becomes a greater hazard than with metal structure.

(7) Physics and mechanics of the crashworthiness for composite structures involve several issues. The local strength, energy absorbing characteristics and multiple, competing failure modes need to be addressed for composite structure subjected to a survivable crash. This is not simply achieved for airframe structures made from Anisotropic, quasi-brittle, composite materials. As a result, the accelerations and load histories experienced by passengers and equipment on a composite aircraft may differ significantly from that seen on a similar metallic aircraft unless specific considerations are designed into the composite structure. In addition, care should be taken when altering composite structure to achieve specific mechanical behaviours. (For example, where the change in behaviour of a metallic structure with a change in material thickness may be easily predicted, an addition of plies to a composite laminate may significantly alter the failure mode and energy absorption characteristics of a composite element.).

(8) Specific composite design and process details must be included to gain valid test and analysis results. Depending on aircraft loading (requiring investigation of various aircraft passenger and cargo configurations), structural dynamic considerations and progressive failures, local strain rates and loading conditions may differ throughout the structure. Sensitivity of the structural behaviour to reasonable impact orientation should also be considered for large aeroplane and rotorcraft applications. Any specific investigation used to gain confidence in a particular structural behaviour, such as studies on the vertical drop for a survivable range of speeds, should also include evaluation for a range of reasonable pitch, roll, yaw, and ground contact conditions (e.g., per CS 25.721), to ensure that the acceptable behaviour is maintained.

(9) Considering a need for comparative assessments with metal structure and a range of crash conditions, analysis with sufficient structural test evidence is often needed for transport and rotorcraft applications. Analysis requires extensive investigation of model sensitivity to modelling parameters (e.g., mesh optimization, representation of joints, element material input stress-strain data). Test also requires investigation of test equipment sensitivity appropriate to composites (e.g., filter frequencies with respect to expected pulse characteristics in the structure). Model validation may be achieved using a building block approach, culminating in an adequately complex test (e.g., a drop test with sufficient structural details to properly evaluate the crashworthiness criteria).

b. Fire Protection, Flammability and Thermal Issues.

(1) Fire and exposure to temperatures that exceed maximum operating conditions require special considerations for composite airframe structure. (See note below.) Requirements for flammability and fire protection of aircraft structure attempt to minimize the hazard to occupants in the event that flammable materials, fluids, or vapours ignite. Compliance may be shown by tests or analysis supported by test evidence. A composite design, including repair and alterations, should not decrease the existing level of safety relative to metallic structure. In addition, maintenance procedures should be available to evaluate the structural integrity of any composite aircraft structures exposed to fire and temperatures above the maximum operating conditions substantiated during design.

Note: Aircraft cabin interiors and baggage compartments have been areas of flammability concerns in protecting passenger safety. This revision of the AMC does not address composite materials used in aircraft interiors and baggage compartments. Please consult other guidance materials for acceptable means of compliance with flammability rules for interiors.

(2) Fire protection and flammability has traditionally been considered for engine mount structure, firewalls, and other powerplant structures that include composite elements. Additional issues critical to passenger safety have come with the expanded use of composites in wing and fuselage structures for large aeroplanes. Existing regulations do not address the potential for the airframe structure itself to be flammable. Wing and fuselage applications should consider the effects of composite design and construction on the resulting passenger safety in the event of in-flight fires or emergency landing conditions, which combine with subsequent egress when a fuel-fed fire is possible.

(3) The results of fire protection and flammability testing with structural composite parts indicate dependence upon overall design and process details, as well as the origin of the fire and its extent. For example, the overall effects of composite fuselage structures exposed to fire may be significantly different when the fire originates within the cabin, where it can be controlled by limiting the structure’s contribution to spreading the fire, than when the fire occurs exterior to the fuselage after a crash landing, where fuel is likely to be the primary source for maintaining and spreading the fire. The threat in each case is different, and the approach to mitigation may also be different. In-flight fire safety addresses a fire originating within the aircraft due to some fault, whereas post-crash fire safety addresses a fuel fed pool fire external to the aircraft. Special conditions are anticipated for large aeroplanes with fuselage structure subjected to both in-flight and post-crash fire conditions. Large aeroplane wing structure will need to have special conditions for post-crash fire conditions.

(4) For an in-flight fire, it is critical that the fire not propagate or generate hazardous quantities of toxic by-products. In-flight fires have been catastrophic when they can grow in inaccessible areas. Composite fuselage structure could play a role different than traditional metal structure if the issue is not addressed.

(5) Metallic transport fuselage and wing structures have established a benchmark in fire protection that can be used to evaluate specific composite wing and fuselage structural details. Exterior fire protection issues associated with composite transport structure must include the effects of an exterior pool fire following a survivable crash landing. Fuselage structure should provide sufficient time for passenger egress, without fire penetration or the release of gasses and/or materials that are either toxic to escaping passengers or could increase the fire severity. Furthermore, these considerations must be extended to wing and fuel tank structure, which must also be prevented from collapse and release of fuel (including consideration of the influence of fuel load upon the structural behaviour).

(6) The exposure of composite structures to high temperatures needs to extend beyond the direct flammability and fire protection issues to other thermal issues. Many composite materials have glass transition temperatures, which mark the onset of large reductions in strength and stiffness that are somewhat lower than the temperatures that can have a similar affect on equivalent metallic structure. The reduced strength or stiffness of composites from high temperature exposures must be understood per the requirements of particular applications (e.g., engine or other system failures). After a system failure and/or known fire, it may be difficult to detect the full extent of irreversible heat damage to an exposed composite structure. As a result, composite structures exposed to high temperatures may require special inspections, tests and analysis for proper disposition of heat damage. All appropriate damage threats and degradation mechanisms need to be identified and integrated into the damage tolerance and maintenance evaluation accordingly. Reliable inspections and test measurements of the extent of damage that exists in a part exposed to unknown levels of high temperatures should be documented. Particular attention should be given to defining the maximum damages that likely could remain undetected by the selected inspection procedures.

c. **Lightning Protection.** Lightning protection design features are needed for composite aircraft structures. Carbon fibre composites are approximately one thousand times less electrically conductive than aluminium, and composite resins and adhesives are non-conductive. Glass and aramid fibre composites are non-conductive. A lightning strike to composite structures can result in structural failure, and induce high lightning current and voltage on metal hydraulic tubes, fuel system tubes, and electrical wiring if proper conductive lightning protection is not provided. Aircraft lightning protection design guidance can be found in the FAA Technical Report "Aircraft Lightning Protection Handbook" (DOT/FAA/CT-89/22). The lightning protection effectiveness for composite structures should be demonstrated by tests. Such tests are typically performed on panels, coupons, subassemblies, or coupons representative of the aircraft structure, or tests on full aircraft. The lightning test waveforms and lightning attachment zones are defined in EUROCAE ED-84 and ED-91. Any structural damage observed in standard lightning tests should be limited to Category 1, 2 or 3, depending on the level of detection. This damage is characterised and integrated into damage tolerance analyses and tests as appropriate. Small simple aeroplanes certified under CS-23 for VFR use only may be certified based on engineering assessment, according to AC 23-15A. The effects of composite structural repairs and maintenance on the lightning protection system should be evaluated. Repairs should be designed to maintain lightning protection.

(1) Lightning Protection for Structural Integrity.

(a) The composite structural design should incorporate the lightning protection appropriate for the anticipated lightning attachment. The extent of lightning protection features depends on the lightning attachment zone designated for that area of the aircraft. Typical lightning protection features include adding metal wires or mesh to the outside surface of the composite structure where direct lightning attachment is expected.

(b) When lightning strikes an aircraft, very high currents flow through the airframe. Proper electrical bonding must be incorporated between structural parts. This is difficult to achieve for moveable parts (i.e., ailerons, rudders and elevators). The electrical bonding features must be sized to conduct the lightning currents or they can vaporize, sending the high currents through unintended paths such as control cables, control rods, or hydraulic tubes. Guidance for certification of lightning protection of aircraft structures can be found in EUROCAE ED-113.

(2) Lightning Protection for Fuel Systems.

(a) Special consideration must be given to the fuel system lightning protection for an aircraft with integral fuel tanks in a composite structure. Composite structure with integral fuel systems must incorporate specific lightning protection features on the external composite surfaces, on joints, on fasteners, and for structural supports for fuel system plumbing and components to eliminate structural penetration, arcing, sparks or other ignition sources. AC 20-53B provides certification guidance for aircraft fuel system lightning protection.

(b) Large aeroplane regulations for fuel system ignition prevention in CS 25.981 require lightning protection that is failure tolerant. As a result, redundant lightning protection for composite structure joints and fasteners are needed to ensure proper protection in preventing ignition sources.

(3) Lightning Protection for Electrical and Electronic Systems.

(a) Lightning strike protection of composite structures is needed to avoid inducing high lightning voltages and currents on the electrical and electronic system wiring, with a potential for system upset or damage. The consequences from a lightning strike of unprotected composite structures can be catastrophic for electrical and electronic systems that perform highly critical functions, such as fly-by-wire flight controls or engine controls.

(b) Electrical shields over system wiring and robust circuit design of electrical and electronic equipment both provide some protection against system upset or damage due to lightning. Since most composite materials provide poor shielding, at best, metal foil or mesh is typically added to the composite structure to provide additional shielding for wiring and equipment. Electrical bonding between composite structure parts and panels should be provided for the shielding to be effective. EUROCAE ED-81 and ED-107 provide certification guidance for aircraft electrical and electronic system lightning protection.

Appendix 1 - Applicable Regulations and Relevant Guidance

1. Applicable Regulations. A list of applicable regulations is provided for subjects covered in this AMC (see notes). In most cases, these regulations apply regardless of the type of materials used in aircraft structures.

Text Paragraphs	**CS-23**	**CS-25**	**CS-27**	**CS-29**
1. Purpose of this AMC	Not Applicable			
2. To Whom this AMC Applies	Not Applicable			
3. Cancellation	Not Applicable			
4. Related Regulations and Guidance	Not Applicable			
5. General	Not Applicable			
6. Material and Fabrication Development	603	603	603	603
	605	605	605	605
	609	609	609	609
	613	613	613	613
	619	619	619	619
7. Proof of Structure – Static	305	305	305	305
	307	307	307	307
8. Proof of Structure – Fatigue and Damage Tolerance	573	571	571	571
9. Proof of Structure – Flutter	629	629	629	629
10. Continued Airworthiness	1529	1529	1529	1529
	App. G	App. H	App. A	App. A
11. Additional Considerations				
a. Crashworthiness (including impact dynamics)	561	561	561	561
	562	562	562	562
	601	601	601	601
		631		631
	721	721		
	783	783	783	783
	785	785	785	785
	787	787	787	787
	807	789	801	801
	965	801	807	803
	967	809	965	809
		963		963
		967		967
		981	1413	

Text Paragraphs	**CS-23**	**CS-25**	**CS-27**	**CS-29**
b. Fire Protection, Flammability and Thermal Issues				
	609	609	609	609
	787	787		
	853	853	853	853
	855	855	855	855
	859	859	859	859
			861	861
	863	863	863	863
	865	865		
		867		
	903	903		903
	967	967	967	967
	1013	1013		1013
	1121	1121	1121	1121
	1181	1181		1181
	1182	1182		
	1183	1183	1183	1183
		1185	1185	1185
			1187	1187
	1189	1189	1189	1189
	1191	1191	1191	1191
	1193	1193	1193	1193
		1194	1194	
	1195	1195	1195	1195
	1197	1197		1197
	1199	1199		1199
	1201	1201		1201
	1203	1203		1203
		1207		
c. Lightning Protection * see AMC 25.899 para.6				
		581*		
	609	609	609	609
			610	610
	867			
		899*		
	954	954*	954	954
		981		
	1309		1309	1309
		1316		

Notes:

(1) This list may not be all inclusive and there may be differences between certification agencies (e.g. FAA and EASA).

(2) Special conditions may be issued in accordance with Part 21 21A.16B for novel and unusual design features (e.g., new composite materials systems).

2. Guidance.

FAA issues guidance providing supportive information of showing compliance with regulatory requirements. Guidance may include the advisory circulars (AC) and policy statements (PS). In general, an AC presents information concerning acceptable means, but not the only means, of complying with regulations. These FAA documents can be located via website: http://www.airweb.faa.gov. In addition, EUROCAE have developed industry standards that are recognised by the Agency. The guidance listed below is deemed supportive to the purposes of this AMC 20-29 and may be used in the absence of alternative EASA AMC, subject to Agency agreement.

Note: Many of the FAA documents are harmonised with EASA. Applicants should confirm with EASA if in doubt regarding the status and acceptance of any such documents by EASA.

a. FAA Advisory Circulars / EUROCAE guidance documents

- AC 20-53B "Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning" [6/06]
- AC 20-135 "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria" [2/90]
- AC 21-26 "Quality Control for the Manufacture of Composite Structures" [6/89]
- AC 21-31 "Quality Control for the Manufacture of Non-Metallic Compartment Interior Components" [11/91]
- AC 23-15A "Small Airplane Certification Compliance Program" [12/03]
- AC 23-20 "Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems" [9/03]
- AC 25.571 -1C "Damage Tolerance and Fatigue Evaluation of Structure" [4/98]
- AC 29 MG 8 "Substantiation of Composite Rotorcraft Structure" [4/06]
- AC 35.37-1A "Guidance Material for Fatigue Limit Tests and Composite Blade Fatigue Substantiation" [9/01]
- AC 145-6 "Repair Stations for Composite and Bonded Aircraft Structure" [11/96]
- EUROCAE ED-81 "Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning"
- EUROCAE ED-84 "Aircraft Lightning Environment and Related Test Waveforms"
- EUROCAE ED-91 "Aircraft Lightning Zoning"
- EUROCAE ED-107 "Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF)"
- EUROCAE ED-113 Aircraft Lightning Direct Effects Certification

b. FAA Policy Statements

- "Static Strength Substantiation of Composite Airplane Structure" [PS-ACE100-2001-006, December 2001]
- "Final Policy for Flammability Testing per 14 CFR Part 23, Sections 23.853, 23.855 and 23.1359" [PS-ACE100-2001-002, January 2002]
- "Material Qualification and Equivalency for Polymer Matrix Composite Material Systems" [PS-ACE100-2002-006, September 2003]
- "Bonded Joints and Structures - Technical Issues and Certification Considerations" [PS-ACE100-2005-10038, September 2005]

Appendix 2 – Definitions

The following definitions are applicable to AMC 20-29 and relevant CS paragraphs only.

Allowables – material values that are determined from test data at the laminate or lamina level on a probability basis (e.g., A or B base values, with 99% probability and 95% confidence or 90% probability and 95% confidence, respectively). The amount of data required to derive these values is governed by the statistical significance (or basis) needed.

Anisotropic – not isotropic; having mechanical and/or physical properties which vary with direction relative to natural reference axes inherent in the material.

Arrested Growth Approach – a method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads with flaw growth which is either mechanically arrested or terminated before becoming critical (residual static strength reduced to limit load). This is to be associated with appropriate inspection intervals and damage detectability.

Category of Damage – One of five categories of damage (See Section 8(a)(1)(c)) based on residual strength capability, required load level, detectability, inspection interval, damage threat and whether (or not) the event creating damage is self evident.

Component – a major section of the airframe structure (e.g., wing, body, fin, horizontal stabilizer) which can be tested as a complete unit to qualify the structure.

Coupon – a small test specimen (e.g., usually a flat laminate) for evaluation of basic lamina or laminate properties or properties of generic structural features (e.g., bonded or mechanically fastened joints).

Critical Structure – a load bearing structure/element whose integrity is essential in maintaining the overall flight safety of the aircraft. This definition was adopted for this AMC because there are differences in the definitions of primary structure, secondary structure and principle structural elements when considering the different categories of aircraft.

Damage – a structural anomaly caused by manufacturing (processing, fabrication, assembly or handling) or service usage.

Debond – (same as Disbond)

Degradation – the alteration of material properties (e.g., strength, modulus, coefficient of expansion) which may result from deviations in manufacturing or from repeated loading and/or environmental exposure.

Delamination – the separation of the layers of material in a laminate. This may be local or may cover a large area of the laminate. It may occur at any time in the cure or subsequent life of the laminate and may arise from a wide variety of causes.

Design Values – material, structural elements, and structural detail properties that have been determined from test data and chosen to assure a high degree of confidence in the integrity of the completed structure. These values are most often based on allowables adjusted to account for actual structural conditions, and used in analysis to compute margins-of-safety.

Detail – a non-generic structural element of a more complex structural member (e.g., specific design configured joints, splices, stringers, stringer runouts, or major access holes).

Disbond – an area within a bonded interface between two adherents in which an adhesion failure or separation has occurred. It may occur at any time during the life of the substructure and may arise from a wide variety of causes. Also, colloquially, an area of separation between two laminae in the finished laminate (in this case the term "delamination" is normally preferred.)

Discrepancy – a manufacturing anomaly allowed and detected by the planned inspection procedure. They can be created by processing, fabrication or assembly procedures.

Element – a generic part of a more complex structural member (e.g., skin, stringers, shear panels, sandwich panels, joints, or splices).

Environment – external, non-accidental conditions (excluding mechanical loading), separately or in combination, that can be expected in service and which may affect the structure (e.g., temperature, moisture, UV radiation, and fuel).

Factor(s):

- **Life (or Load) Enhancement Factor** - an additional load factor and/or test duration applied to a structure test, relative to the intended design load and life values, used to account for material variability. It is used to develop the required level of confidence in data.
- **Life Scatter Factor** – (same as Life/Load Enhancement Factor)
- **Overload Factor** – a load factor applied to a specific structure test which is used to address parameters, e.g. environment, a short test pyramid etc, not directly addressed in that test. This factor is usually developed from lower pyramid testing addressing such parameters.

Heterogeneous – descriptive term for a material consisting of dissimilar constituents separately identifiable; a medium consisting of regions of unlike properties separated by internal boundaries.

Intrinsic Flaw – defect inherent in the composite material or resulting from the production process.

No-Growth Approach - a method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads without detectable flaw growth for the life of the structure

Primary Structure – primary structure is that structure which carries flight, ground, or pressurization loads, and whose failure would reduce the structural integrity of the aircraft.

Point Design – an element or detail of a specific design which is not considered generically applicable to other structure for the purpose of substantiation, e.g., lugs and major joints. Such a design element or detail can be qualified by test or by a combination of test and analysis.

Slow Growth Approach - a method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads without significant flaw growth for the life of the structure, or beyond appropriate inspection intervals associated with appropriate damage detectability. The growth rate must be shown to be slow, stable, and predictable.

Structural Bonding – a structural joint created by the process of adhesive bonding, comprising of one or more previously-cured composite or metal parts (referred to as adherends).

Sub-component – a major three-dimensional structure which can provide completed structural representation of a section of the full structure (e.g., stub-box, section of a spar, wing panel, wing rib, body panel, of frames).

Weak Bond – a bond line with mechanical properties lower than expected, but without any possibility to detect that by normal NDI procedures. Such situation is mainly due to a poor chemical bonding.

Appendix 3 - Change of Composite Material and/or Process

1. Any certificated composite structures, intended to incorporate substitutions of, or changes to, the materials and/or processes from those originally substantiated at the time of initial certification, must be subject to a change approval. For example, the original material supplier may either change its product, or cease production. Manufacturers may also find it necessary to modify their production processes to improve efficiency or correct product deficiencies. In either case, care must be taken to ensure that modifications and/or changes are investigated to ensure the continued airworthiness of the changed composite structure. This appendix covers such material and/or process changes, but does not address other changes to design (e.g., geometry, loading). The definition of the materials and processes used is required in the specifications by Part 21A.31. Changes to the material and process specifications are often major changes in type design and must be addressed as such under Part 21, subpart D or E as applicable.

2. The qualification and structural substantiation of new or modified materials and/or processes used to produce parts of a previously certified aircraft product requires: (i) the identification of the key material and/or process parameters governing performances, (ii) the definition of the appropriate tests able to measure these parameters, and (iii) definition of pass/fail criteria for these tests.

3. 'Qualification' procedures developed by every manufacturer include specifications covering:
  a. Physical and chemical properties,
  b. Mechanical properties (coupon level),
  c. Reproducibility (by testing several batches).

4. Specifications and manufacturing quality procedures are designed to control specific materials and processes to achieve stable and repeatable structure for that combination of materials and processes. However, the interchangeability of alternate materials and processes for a structural application can not be assumed if one only considers the properties outlined in those specifications (as it could be for materials that are much less process dependent, e.g., metallic materials). A structure fabricated using new or modified materials and/or processes, which meet the 'qualification' tests required for the original material and process specifications, does not necessarily produce components that meet all the original engineering requirements for the previously certified structure.

5. Until improvements in identifying the complex relations between key material parameters that govern composite processing occurs, there will be a need for extensive and diverse testing that directly interrogates material performance using a range of representative specimens of increasing complexity in building block tests. Furthermore, failure modes may vary from one material and/or process to another, and analytical models are still insufficiently precise to reliably predict failure without sufficient empirical data. Therefore, a step-by-step test verification with more complex specimens is required.

6. Classification of Material or Process Change.

Material and/or process changes require appropriate classification in order to aid the determination of the extent of investigation necessary. Some minor changes may only require material equivalency sampling tests to be completed at the base of the test pyramid, whilst more significant changes will require more extensive investigations, including possibly a new structural substantiation.

a. Any of the following situations requires further investigation of possible changes to a given composite structure:

- Case A: A change in one or both of the basic constituents, resin, or fibre (including sizing or surface treatment alone), would yield an alternate material. Other changes that result in an alternate material include changes in fabric weave style, fibre aerial weight and resin content.

- Case B: Same basic constituents but any change of the resin impregnation method. Such changes include: (i) prepregging process (e.g. solvent bath to hot melt coating), (ii) tow size (3k, 6k, 12k) with the same fibre areal weight, (iii) prepregging machine at the same suppliers, (iv) supplier change for a same material (licensed supplier).
- Case C: Same material but modification of the processing route (if the modification to the processing route governs eventual composite mechanical properties). Example process changes of significance include: (i) curing cycle, (ii) bond surface preparation, (iii) changes in the resin transfer moulding process used in fabricating parts from dry fibre forms, (iv) tooling, (v) lay-up method, (vi) environmental parameters of the material lay-up room, and (vii) major assembly procedures.

b. For each of the above cases, a distinction should be made between those changes intended to be a replica of the former material/process combination (cases 'B' and some of case 'C') and those which are 'truly new material' (case 'A' and some of case 'C'). So, two classes are proposed:

- 'Identical materials/processes' in cases intended to create a replica structure.
- 'Alternative materials/processes' in cases intended to create truly new structure.

c. Within the 'identical materials/processes' class, a sub-classification can be made between a change of the prepregging machine alone at the supplier and licensed production elsewhere. For the time being, a change to a new fibre produced under a licensed process and reputed to be a replica of the former one, will be dealt with as an 'alternative material/process.'

d. Some minor changes within the class representing identical materials/processes may not interact with structural performances (e.g., prepreg release papers, some bagging materials, etc.) and should not be submitted to an agency as part of the change. However, the manufacturers (or the supplier) should develop a proper system for screening those changes, with adequate proficiency at all relevant decision levels. Other minor material changes that fall under Case B may warrant equivalency sampling tests only at lower levels of building block substantiation.

e. Case 'C' changes that may yield major changes in material and structural performance need to be evaluated at all appropriate levels of the building block tests to determine whether the manufacturing process change yields identical or alternate materials. Engineering judgment will be needed in determining the extent of testing based on the proposed manufacturing change.

f. Case 'A' (alternative material) should always be considered as an important change, which requires structural substantiation. It is not recommended to try a sub-classification according to the basic constituents being changed, as material behaviour (e.g., sensitivity to stress concentrations) may be governed by interfacial properties, which may be affected either by a fibre or a resin change.

7. **Substantiation Method.** Only the technical aspects of substantiation are addressed here.

a. **Compliance Philosophy**. Substantiation should be based on a comparability study between the structural performances of the material accepted for type certification, and the second material. Whatever the modification proposed for a certificated item, the revised margins of safety should remain adequate. Any reduction in the previously demonstrated margin should be investigated in detail.

(1) Alternative Material/Process: New design values for all relevant properties should be determined for any alternate material/process combination. Analytical models initially used to certify structure, including failure prediction models, should be reviewed and, if necessary, substantiated by tests. The procurement specification should be modified (or a new specification suited to the selected material should be defined) to ensure key quality variations are adequately controlled and new acceptance criteria defined. For example, changing from first to second generation of carbon fibres may improve tensile strength properties by more than 20% and a new acceptability threshold will be needed in the specification of the alternate material to ensure the detection of quality variations.

(2) Identical Material: Data should be provided that demonstrates that the original design values (whatever the level of investigation, material or design) remain valid. Statistical methods need to be employed for data to ensure that key design properties come from the same populations as the original material/process combination. Calculation models including failure prediction should remain the same. The technical content of the procurement specification (case 'B') should not need to be changed in properly controlling quality.

b. Testing.

(1) The extent of testing needed to substantiate a material change should address the inherent structural behaviour of the composite and will be a function of the airworthiness significance of the part and the material change definition. For example, the investigation level might be restricted to the generic specimens at the test pyramid base (see figures in paragraph 6) for an identical material, but non-generic test articles from higher up the pyramid should be included for an alternative material. Care needs to be taken to ensure that the test methods used yield data compatible with data used to determine properties of the original structure.

(2) The testing that may be required for a range of possible material and/or process changes should consider all levels of structural substantiation that may be affected. In some instances (e.g., a minor cure cycle change), possible consequences can be assessed by tests on generic specimens only. For other changes, like those involving tooling (e.g., from a full bag process to thermo-expansive cores), the assessment should include an evaluation of the component itself (sometimes called the 'tool proof test'). In this case, an expanded non destructive inspection procedure should be required for the first items to be produced. This should be supplemented – if deemed necessary – by 'cut up' specimens from a representative component, for physical or mechanical investigations.

c. Number of Batches.

(1) The purpose for testing a number of batches is the demonstration of an acceptable reproducibility of material characteristics. The number of batches required should take into account: material classification (identical or alternative), the investigation level (non-generic or generic specimen) the source of supply, and the property under investigation. Care should be taken to investigate the variation of both basic material and the manufacturing process.

(2) Existing references (e.g., The Composite Materials Handbook (CMH-17) Volumes 1 and 3, FAA Technical Report DOT/ FAA/AR-03/19), addressing composite qualification and equivalence and the building block approach, provide more detailed guidance regarding batch and test numbers and the appropriate statistical analysis up to laminate level. Changes at higher pyramid levels, or those associated with other material forms, e.g., Braided VARTM structure, may require use of other statistical procedures or engineering methods.

d. **Pass/Fail Criteria.** Target pass/fail criteria should be established as part of the test programme. For strength considerations for instance, a statistical analysis of test data should demonstrate that new design values derived for the second material provide an adequate margin of safety. Therefore, provision should be made for a sufficient number of test specimens to allow for such analysis. At the non-generic level, when only one test article is used to assess a structural feature, the pass criteria should be a result acceptable with respect to design ultimate loads. In the cases where test results show lower margins of safety, certification documentation will need to be revised.

e. **Other Considerations.** For characteristics other than static strength (all those listed in AMC 20-29, paragraphs 8, 9, 10 and 11, the substantiation should also ensure an equivalent level of safety).

C. Appendix to NPA

I. Comment/Response Document from workshop held on 28th January 2009

On 28th January 2009, the Agency arranged a workshop for industry with the twin objectives of providing an outline of the intended revisions to CSs and to prepare industry for release of the NPA for public comment.

This Appendix reports on comments raised at or subsequent to the meeting, together with the Agency's responses.

Further details on the Workshop, together with related documents and presentations, can be found on the EASA website at; http://www.easa.europa.eu/ws_prod/g/g_events.php

Comment on draft AMC 20-29	Response
General Concern was expressed that this is a Design Certification document and now appears to be too broad in its scope, encompassing activities believed to be beyond the design process and/or not defining exactly what needs to be done to show compliance, e.g. maintenance, training etc. It was suggested that content be removed, or the document reorganised, e.g. content not directly related to design be placed in an appendix.	Composite design (probably more so than metallic design) needs to address this broader range of considerations due to the more integrated link between material properties and the production/repair process. The design approval holder is best placed to define such activities, partly through the certification process (already recognised for CAW ref. 25.1529 etc). At a more generic level, the need for a stronger formal link between these broader activities is evident in the Operational Suitability Certificate (OSC) NPA 2009/01. Furthermore, the Agency believes that industry wishes to benefit from globally harmonised generic documentation. However, an inevitable outcome of such a process is some level of compromise. Therefore, unless such compromise, e.g. details of organisation for this guidance document, creates a disadvantage for European Industry, then it should be retained. Reorganisation, for other than significant reasons, will offer further opportunity for inconsistent interpretation, thus undoing the potential benefits of harmonisation.
General Rotorcraft industry perceived this document as an additional layer of regulation. Text needs to be amended to make clear that this document is not intended to supersede, but complement, existing documentation, e.g. AC 29 2C MG8	The intent is to provide a broader complementary document for the rotorcraft industry which does not replace the existing guidance. This new AMC was developed, partly, from the generically appropriate elements of the well developed, and respected, harmonised rotorcraft document AC 29 2C MG8. The Agency has added text to the draft AMC, para.3, to make this point.
General The need to include, Very Light Aircraft (CS-VLA), Propeller (CS-P), and Engine (CS-E).	This was discussed within the working group. However, although many aspects of the CSs would be common to this AMC, it was considered that this document would become unmanageable at this time, but the Agency would consider their inclusion in a future revision.
General One commentator pointed out that it is better to have this guidance now to reduce the chance of needing more stringent regulation later as the result of an accident .	Accepted

Comment on draft AMC 20-29	Response
6. Material & Fabrication Development Concern expressed regarding inclusion of metal-metal bonding. It was suggested that this be removed and/or a new AC/AMC be specifically produced.	The Agency agrees that metal bonding could justify a separate AMC. However, such an activity would take time and resources significantly beyond the timescale for the objectives for this document. The Agency intends to retain the text in this AMC because it is considered to also be valid and applicable to metal bonding.
6. Material & Fabrication Development Should Glare be included? No firm position provided from the group.	The Agency understands that Glare is a significant product. However, it is considered to be too specific relative to the level of discussion in the AMC.
7. Proof of Structure – Static Concern was expressed regarding removal of AMC No.1 to CS 25.603 Composite Aircraft Structure, paragraph 5.7	Although paragraph 7 of the new AMC does not explicitly repeat 5.7, the Agency believes that the draft text does not exclude this as a possible approach to showing compliance. Acceptance of such an approach would be a function of similar experience with similar design etc.
8. Proof of Structure – Fatigue and Damage Tolerance Suggested that Category 5 should not be included here (possibly in an appendix) because it is not a certification requirement.	The Agency agrees that this initially may appear to be outside the certification process. However, as EASA and industry still need to understand the potential for significant damage with little damage indication, it is important to emphasis the issue in order to justify such an assumption (large passenger aircraft pressure hulls being a particular concern at this time). The Category 5 concept does this well and is best expressed and bounded in relation to the other categories at this location in the text. Furthermore, certification links, e.g. training maintenance requirements, may be established relative to the Category 5 concept via the Operational Suitability Certificate (OSC) NPA 2009/01.
8. Proof of Structure – Fatigue and Damage Tolerance The different wording relating to the need for repair in the definitions for Category 4 and 5 was considered to be potentially unclear.	The Agency requests the commenter to explain the concern further.
8. Proof of Structure – Fatigue and Damage Tolerance **b. Fatigue Evaluation** It was believed that LoV should be used, not retirement. Note: the intent in the document was to refer to a substantiated life (which could be extended with appropriate justification?). If terminology is an issue then it may need to change. It is the concept that matters.	Text has been changed to avoid the problem with this specific terminology whilst, retaining the idea.
8. Proof of Structure – Fatigue and Damage Tolerance, **b. Fatigue Evaluation** Identify stiffness as an important measure of degradation and as a possible part of the life assessment process.	The Agency agrees that stiffness degradation may provide a useful part of the assessment for the purposes of life determination. However, stiffness (icw strength) degradation is a theme throughout the F&DT discussions.
8. Proof of Structure – Fatigue and Damage Tolerance, **b. Fatigue Evaluation** Reference the problem with removable LoV parts and tracking.	The Agency agrees that this is a concern. However, this is a generic problem for all removable lifed parts (metallic and composites).
10. Continued Airworthiness, **c. Substantiation of Repair.** Also applies to Cat 2, not just 3,4, 5	The use of the word special was intended to mean instructions beyond those provided in existing typical design approval holder documents, e.g. SRM, MM etc.

Comment on draft AMC 20-29	Response
10. Continued Airworthiness, **d. Damage Detection, Inspection and Repair Competency.** Concern about applicability of this to design function (as per earlier comment)	See earlier responses relating to scope of document
11. Additional Considerations. **a. Crashworthiness.** Not linked to a specific requirement in some CSs (e.g. CS-27 & 29).	The Agency considers that there is value in expressing current thinking in AMC text. Any application of such approaches for the purposes of certification would be limited by the need to show applicability and/or any further evolution in the SC.
11. Additional Considerations. **a. Crashworthiness.** Concern that this content was too generic	The Agency considers that the expression of some generic principles is useful because existing requirements are distributed throughout some CSs. The Agency also recognises that each CS has some unique requirements, see comments above. However, any attempt to discuss these requirements at a more detailed level would expand the text too much to be manageable.
11. Additional Considerations. **b. Fire Protection, Flammability and Thermal Issues** Repetition in the detailed text	The Agency agrees that some repetition does occur, e.g. relating to thermal issues, paragraph 11(b)(6), but does not consider the repetition to be excessive.
11. Additional Considerations. **c. Lightning Protection.** Scale dependent	The Agency agrees that significance of lightning damage may be scale dependent. However, the point being made is that damages need to be categorised etc. This should take into account the design, zoning, and the damage size.
Appendix 2: Definitions Reference to A and B- basis should be removed from the 'Allowables' definition – these having been removed from the rules, i.e. 25.613.	The reference to A and B-basis is only by example in this guidance material. Furthermore, the new AMC makes reference to statistical guidance.
Appendix 2: Definitions 'Critical Structure' definition was considered to be controversial because it could be confusing and introduce yet more terminology, this not being introduced by direct rule. Furthermore, this terminology was thought to conflict with CS-25 F&DT requirements. Most attendees wished to remove this definition. PSE was offered as the most popular alternative (although this would not address potentially catastrophic non-PSE structure). Note that the existing document generically addresses 'composite structure'. The rules associated with each section in the document would govern which structure needs to be considered under the appropriate CS. This needs to be reviewed.	This was terminology adopted to ease reading of the document. The intent was for the term 'Critical Structure' to mean structure as defined and appropriate to each CS. The definition of 'Critical Structure' has been expanded to make this point.