Notification of a Proposal to issue a Certification Memorandum

Composite Materials - The Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications

EASA Proposed CM No.: Proposed CM–S-010 Issue 01 issued 10 June 2016

Regulatory requirement(s): **AMC 20-29 (CS-23 – commuter aircraft, CS-25, CS-27 and CS-29)**

In accordance with the EASA Certification Memorandum procedural guideline, the European Aviation Safety Agency proposes to issue an EASA Certification Memorandum (CM) on the subject identified above.
All interested persons may send their comments, referencing the EASA Proposed CM Number above, to the e-mail address specified in the "Remarks" section, prior to the indicated closing date for consultation.

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EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

Log of issues

Issue	Issue date	Change description
01	10.06.2016	First issue.

Table of Content

1. Introduction

1.1. Purpose and scope

This Certification Memorandum (CM) provides EASA guidance relating to the safe design and use of monocoque sandwich structures in critical structure applications (‘critical structure’ as defined in AMC 20-29), particularly those structures with single load paths.

This CM has been written in response to some in-service incidents and incorrectly predicted test failure loads and/or modes and/or locations and is applicable to fixed wing and rotorcraft applications.

It is recognized that the behaviour of sandwich structures is dependent upon configuration details and that the use of sandwich structures in monocoque critical single load path structure applications tends to be associated with thicker skin and heavier core configurations than is typical of control surface and high lift device designs. Therefore, this CM does not attempt to address all issues associated with sandwich structures of control surfaces and high lift devices, such as the effect of pressure cycles. Pressure cycles may occur in a sealed sandwich structure due to both changes in the external atmospheric pressure or changes in temperature of the gases in the core and have resulted in the failure of thinner skin and lower density core sandwich structures, including repairs of such structure. This is the subject of a current CMH-17 working group activity and may result in subsequent CM action. However, this CM does benefit from some of the applicable ‘lessons learned’ relating to these structures.

This CM does not explicitly address all Static Strength, Fatigue, and Damage Tolerance (F&DT) requirements as may be associated with all product types, but simply intends to support such requirements by ensuring robust design. For example, subject to product and configuration specific F&DT design philosophy, applicants considering monocoque sandwich structure pressure hulls may be expected to show Continued Safe Flight and Landing (CSF&L) and/or Limit Load capability with extensive areas of skin and/or core damage associated with all threats defined in AMC 20-29. Therefore, it is particularly important for such applicants to discuss intent to develop such a design with the regulator early in the product development.

1.2. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date
CS 2X.305	Strength and Deformation	CS-2X	---	---
CS 2X.307	Proof of Structure	CS-2X	---	---
CS 2x.57X	Damage Tolerance and Fatigue	CS-2X	---	---
CS 23.573(a)(5)	Damage tolerance and fatigue evaluation of structure (a) Composite airframe structure	CS-23	---	---
CS 2X.601	General	CS-2X	---	---
CS 27/29.602	Critical Parts	CS-27/29	---	---
CS 2X.603	Materials and workmanship	CS-2X	---	---
CS 2X.605	Fabrication Methods	CS-2X	---	---

Reference	Title	Code	Issue	Date
CS 2X.613	Material Strength Properties and Design Values	CS-2X	---	---
AMC 20-29	Composite Aircraft Structure	CS-2X	---	---
AC 27/29.573	Damage Tolerance and Fatigue Evaluation of Composite Rotorcraft Structures	CS-27/29	---	---

1.3. Abbreviations

AMC	Acceptable Means of Compliance
BC	Boundary Conditions
CM	Certification Memorandum
CMH	Composite Material Handbook
CS	Certification Specification
FAA	Federal Aviation Administration
F&DT	Fatigue & Damage Tolerance
ICA	Instructions for Continued Airworthiness
LL	Limit Load
NDI	Non Destructive Inspection
OSD	Operational Suitability Data
SMS	Safety Management System
UL	Ultimate Load

1.4. Definitions

Adhesion Failure	Separation of the adhesive-adherend interface usually the result of inadequate bonding.
Co-bonded structure	Components bonded together during cure of one, or more, of the components, but not all components, e.g. bonding to metallic or a pre-cured component.
Co-cured Structure	Structure obtained by a single cure of uncured components
Critical Structure	A load bearing structure/element whose integrity is essential in maintaining the overall flight safety of the aircraft. (AMC 20-29)

Telegraphing	Excessive undulation of the sandwich panel skin resulting from excessive overpressure during the autoclave process
Weak Bond	A bond line with mechanical properties lower than expected, that cannot be reliably detected using non-destructive inspection (NDI) procedures currently applied by industry. Such situations may result from poor chemical bonding (see AMC 20-29) caused by contaminations of the surfaces including presence of peel ply material left within the structure during the cure
Witness Structure	A structure used in service which provides a defined indication of an event having occurred which may be correlated with other less evident damages elsewhere in critical areas of the airframe related to or aggravated by the same event. Such witness indications may be used to drive further airworthiness actions applicable to all potentially damaged structure, e.g. initiate more detailed inspections, etc. Note: the term 'Witness Structure' should not be confused with witness coupons used in the production process.

2. Background

2.1. General

Sandwich structures have been used successfully in the recent decades for many applications, e.g. small and large fixed wing and rotorcraft applications, including Primary, PSE, and some critical monocoque single load path structures. However, there have also been several significant incidents involving sandwich structures (of various configurations in various applications) which have presented a potentially serious safety concern.

There have also been a growing number of component development and certification test failures which exhibited unexpected or premature failure in terms of load level and/or mode and/or location. Although development tests have not typically been considered to form part of the formal certification process, they can contribute significantly towards gaining confidence in support of the certification of a product, for both the applicant and the certifying agency, such that they are considered to be of increasing value and relevance to the certification process.

These failures have been associated with one or more of the potentially large number of competing damage modes possible in sandwich structures, e.g. ref. CMH-17 Volume 6, some of which are not readily detectable, either visually or by NDI. Therefore, it is considered appropriate to more explicitly emphasise the importance of strict manufacturing processes and a robust Fatigue & Damage Tolerance (F&DT) philosophy which includes identification of all likely damage modes, particularly those resulting from impact. For example, for impact, consideration of all likely impactor geometries and stiffnesses (e.g. for hail) throughout the associated likely energy ranges may be required, etc.

Furthermore, it is also considered to be necessary to simulate all such likely undetectable damage to its full extent during certification tests, in addition to the consideration of disbond or weak bonds as typically included in current design substantiation processes.

Failures in sandwich structures are often attributed to a combination of many factors, including deficiencies in design, production and/or continuing airworthiness. Therefore, it is considered appropriate to emphasise the importance of integrated involvement of all responsible organisations in the supply, design, production, and continuing airworthiness process, i.e. in accordance with SMS and OSD processes as appropriate to the product.

Although it is understood that co-cured structures can generally provide relatively more robust bonding between the constituent parts of the structure than other bonding processes, e.g. co-bonding, it should be noted that the potential exists for any bonded joint to present a challenge. Therefore, this CM also applies to co-cured structures.

2.2. Related regulations

CS 2X.601 Design states the structure:

'(a) …may have no design features or details that experience has shown to be hazardous or unreliable.
(b) The suitability of each questionable design detail and part must be established by tests.'

CS 29.602 Critical Parts states for rotorcraft:

'(a) …A critical part is a part, the failure of which could have a catastrophic effect upon the rotorcraft, and for which critical characteristics have been identified which must be controlled to ensure the required level of integrity.

(b)…Procedures shall be established to define the critical design characteristics, identify processes that affect those characteristics, and identify the design change and process change controls necessary for showing compliance with the quality assurance requirements of Part 21.'

Note: The above text could be interpreted as being applicable to a single load path critical structure of monocoque sandwich construction.

AMC 20-29 Composite Aircraft Structures/ACs 27/29.573 Damage Tolerance and Fatigue Evaluation of Composite Rotorcraft Structures

AMC 20-29 makes clear the expectations for all 'critical structures' regarding materials, design, production, and continued airworthiness. This includes identification of the need to use appropriate F&DT criteria and identifies the unacceptability of any defect remaining undetected such that UL cannot be maintained, e.g. AMC 20-29 Figure 4.

AMC 20-29 also refers to the need to observe linkage to basic strength and data reliability requirements, e.g. CS2X.305, 2X.307, 2X.603, and 2X.613 etc., and also the need to address bonded structure.

AMC 20-29 further identifies the need to consider the potential for disbonded structure, or 'weak bonds', which may remain undetected, and that adhesion failure is unacceptable.

AMC 20-29 refers to AC 21-26 "Quality Control for the Manufacture of Composite Structures"

Note: AMC 20-29 was partly developed from ACs 27/29.573 respectively to provide generic guidance for both fixed wing and rotorcraft. These ACs, and supporting references, provide further guidance specific to rotorcraft bonded/sandwich structures.

3. EASA Certification Policy

3.1. EASA Policy

To satisfy the means of compliance provided in AMC 20-29 for 'critical structures', EASA considers that the use of monocoque sandwich structures (baseline structures and repairs) in single load path critical structure applications should be treated with caution, paying particular attention to the following:

3.1.1. Qualification of the manufacturing process

The manufacturing process has to be fully qualified before starting production of the parts.

The qualification is intended to demonstrate that the combination of material, tooling, equipment, procedures, and other controls, making up the process, will produce representative parts having consistent material properties that conform to design requirements.

As part of the process qualification, destructive and non-destructive inspection (NDI) should be conducted to determine conformity to specified design requirements and check the suitability of the resulting product by assessing features such as :

- Uniformity of the adhesive fillets between honeycomb core cell wall and skin, in particular the process should ensure that on both faces of the honeycomb core a regular shaped fillet (meniscus) be established.
- Absence of ‘telegraphing’ effects and waviness on the skins of the sandwich panel.
- Distortion of the core cells. This defect could be particularly critical for highly curved panels unless suitable precautions are taken during fabrication (e.g. core thermal conforming).
- Presence in the adhesive of unacceptable levels of porosity or humidity.
- Disbonds between core and cells.
- Weak bonds.

3.1.2. Process specifications

Specifications covering fabrication procedures have to be established to ensure that repeatable and reliable structure can be manufactured.

The process specification should include all necessary instructions to manufacture, inspect, and test the produced parts in order to ensure that they consistently conform to the one that has been qualified (see point 3.1.1 above).

The process specification should typically include information required by AC 21-26, paying particular attention to:

- Procedures for accepting the in-coming material (skin and core) and instructions for its handling and storing conditions.
- Instructions for material preparation and curing cycles.
- Inspection procedures and quality control tests.

3.1.3. Material strength and determination of design allowable

Strength properties of the sandwich panels should be established in order to ensure that the probability of structural failure due to material and process variability be minimised.

Because of the peculiarity of the sandwich panel construction, the material properties should be established on specimens fully representative of the panel construction in terms of skin, core material and curing cycle.

Design features such as transition zones from solid laminate to core/skin should also be tested with representative specimens for determination of strength properties.

It is expected that at least the following static allowables be established according to the statistics required under CS 2X.613:

- Adhesive Shear Strength.
- Shear Core Strength (Ribbon and Transverse direction).
- Core Compression Strength.
- Flatwise Strength.
- Flexural Strength.
- Compressive Strength.
- Bearing Strength (for specimen representative of all the panel areas where fasteners are installed and subject to significant bearing stresses.)

In determining the above properties, the effect due to humidity uptake, highest and lowest temperature expected in service, manufacturing defects up to limit of acceptability, impact damages should be also considered.

The validity of engineering formula used to establish analytical design allowables should always be verified by dedicated experimental activity in order to assess the effects of the manufacturing process (e.g. curing pressure which is normally limited to the crush core strength) and environmental conditions on the allowable predicted by these formulas.

It is also expected that relevant fatigue testing at specimen level, representative of design point (e.g. fastened joint) and typical panel configuration be performed in order to assess the effects of on the fatigue strength of:

- Material/Manufacturing Process variability.
- Environmental Condition.
- Allowable manufacturing defects.
- Impact damages.

3.1.4. Damage tolerance and residual strength

3.1.4.1. Threat survey and damage modes

As part of compliance with the applicable F&DT requirements, the applicant should clearly demonstrate that a robust structure has been produced by showing:

- That a thorough damage threat survey has been completed which identifies and defines all threats, including impacts, heat, moisture, etc. and the potential for interaction of these threats is addressed.
- That all damage modes have been identified for the configuration when subject to all likely threats, paying particular attention to all likely damage modes which might not be readily detected.

  For impact threats, this requires testing throughout the threat impact energy ranges up to readily detectable damage using a range of appropriate impactor geometries, e.g. including sharp impactors and blunt impactors up to diameters agreed with EASA (Note: 4 inches diameter impactors have been accepted for CS25 use, based upon typical protection device geometries carried by ground vehicles, if no acceptable alternatives can be proposed based upon an acceptable threat surveys etc.). Furthermore, it may be appropriate to consider a range of impactor stiffnesses, e.g. for hail threat damage, such that all competing damage modes can be identified. Representative boundary conditions should be used in the substantiation test campaign.
- That all potentially undetectable damage modes (not only disbonds, but also inner core shear failure etc) have been simulated in testing (up to appropriate dimensions such that detection becomes possible and the dimensions of such damage have been quantified such that UL can be maintained up to readily detectable levels, or to the limits defined by substantiated design back-up features). The possibility of interaction between threats, e.g. impact and heat, should be considered in the simulation and substantiation process.

  Note: Witness structures, see 'Definitions', can be used in service, to trigger airworthiness actions, provided that a consistent and conservative correlation can be demonstrated to exist between the indications on the witness structure and the damage (all likely modes and extents) considered in the critical structure. For example, subject to appropriate substantiated correlation, hail damage to thin skin structure could be used to determine the need to initiate extensive NDI action for a thicker more critical structure which has the potential for non-visible damage modes etc.

3.1.4.2. Residual strength

Unless the applicant can demonstrate, to the satisfaction of the regulator, robust experience* using similar materials and processes in similar configurations at similar strain levels and in similar service environments, then the monocoque sandwich structures being used in the critical single load path application should be demonstrated to sustain no less than LL capability with obviously detectable damage** for any potentially catastrophic damage modes. Any potentially catastrophic damage mode which may not initially be readily detectable should be identified and addressed for growth up to readily detectable levels for this purpose.

> *Note: The application of 'grandfathered' technology should be treated with caution. A thorough and integrated design and production review should be completed in conjunction with material suppliers in order to ensure that any credit for the 'grandfathered' technology is appropriate for the new product. Extrapolation of data should be treated with particular caution. This is necessary because previous incidents have shown the use of 'grandfathered' technology to sometimes be inappropriate, thus challenging the showing of compliance with CS2x.601.

> **Note: In order to ensure robust design of monocoque sandwich structures in single load path critical structure applications, 'obviously detectable' should be considered to be associated with the larger damages (i.e. large Cat 2 or Cat 3 damages), not the smallest obviously detectable damage. Sizing structure to the latter, e.g. a small detectable hole in the skin, without addressing all other likely potentially catastrophic damage modes, is unlikely to be considered to be an appropriate interpretation of AMC 20-29 or to result in a robust structure, particularly for monocoque sandwich structure used in single load path critical structure applications.

3.1.5. SMS

Recognising that several structural failures have resulted from various combinations of design, production, and continued airworthiness deficiencies, the applicant must clearly demonstrate that the structure has been subjected to the appropriate co-ordinated involvement of material suppliers, the design organisation (TC Holder), production organisations, and those with appropriate continued airworthiness experience throughout the supply, design, development, and certification processes.

The intent of such a co-ordinated effort should be the early identification of hazards and the assessment of potential risks relative to the recognised criticalities and design complexities, the manufacturing process, the envisaged production supply chain and environment, particularly with respect to continued airworthiness implications. Appropriate actions should then be developed and documented for risk mitigation, including the necessary organisational policies and procedures in order to ensure the integrity, efficiency and effectiveness of the action taken in addition to appropriately managing changes when occurring to the approved design and production.

3.1.6. ICA

The ICA must include clear instructions to inspect*, both internally and externally:

- all load paths, e.g. up to load transfer fittings, joints, other significant changes in stiffness and section, for damage following an overload event, e.g. impact, heavy landing, excessive gust etc.,
- all structure regularly exposed to extreme temperatures, e.g. local to engine outlets or aircraft used extensively in hot climates, etc. Although inspection intervals should have been justified according to the level of detectability and residual strength capability during certification substantiation based upon a damage threat survey, experience has indicated the potential for interaction between heat and damage can be problematic.

*paying particular attention to:

- repaired structures
- any existing, and potentially related, ICA, e.g. existing ADs, etc.

The ICA must include adequate information on allowable damage limits, including identification of the NDI techniques and equipment necessary to inspect the structure, and the actions necessary to return the aircraft to an airworthy condition when damage is found.

3.2. Who this Certification Memorandum affects

This CM could affect applicants who need to show compliance with requirements identified in AMC 20-29, e.g. CS-2X.603, 2X.605, and 2X.613, etc. when using monocoque sandwich structure in critical structures, particularly paying attention to single load path applications.

Note: Although primarily addressing CS23 – commuter, CS25, CS27, and CS29, this CM includes content some of which may also provide useful guidance when addressing smaller CS23 and VLA aircraft.

4. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **22nd of July 2016**. Comments received after the indicated closing date for consultation might not be taken into account.
2. Comments regarding this EASA Proposed Certification Memorandum should be referred to the Certification Policy and Safety Information Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu.
3. For any question concerning the technical content of this EASA Proposed Certification Memorandum, please contact:

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