| EASA | NOTIFICATION OF A PROPOSAL TO ISSUE A CERTIFICATION MEMORANDUM |
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| | **EASA Proposed CM No.:**<br>**EASA Proposed CM – S – 005 Issue: 01**<br>**Issue Date: 8th of September 2014**<br>**Issued by: Certification Directorate**<br>**Approved by: Certification Director**<br>**Regulatory Requirement(s): CS 2x.603, AMC 20-29** |

**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 below.**

**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.**

**EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.**

**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.**

# Subject

# Bonded Repair Size Limits in accordance with CS 2x.603 and AMC 20-29

## Log of Issues

| Issue | Issue date | Change description |
|---|---|---|
| 01 | 08.09.2014 | First issue. |

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# 1. INTRODUCTION

## 1.1. PURPOSE AND SCOPE

This Certification Memorandum (CM) provides guidance regarding the determination of Bonded Repair Size Limits for critical composite (monolithic and sandwich) and metallic structures in accordance with CS 2x.603 and AMC 20-29.

This CM primarily addresses certification associated with continued airworthiness as appropriate to both TC holders and non-TC holders, applying for or conducting bonded repair design approval. However, AMC 20-29 also recognises that the engineering properties associated with composite material, and bonded structure in particular, are very dependent upon material and processes which may be completed in service environments. Therefore, this CM also provides some background guidance to the reasons for some repair size limitations, which is also relevant to Part 145 organisations, in particular to their expectations for bonded repair solutions or when fabricating replacement parts.

Note: This CM expresses a harmonised Policy position developed between EASA, FAA, and TCCA.

## 1.2. REFERENCES

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

| Reference | Title | Code | Issue | Date |
|---|---|---|---|---|
| AMC 20-29 | Composite Aircraft Structure | --- | --- | --- |
| AMC 145.A.42(c) | Acceptance of Components | --- | --- | --- |
| Part 21, Subpart J | Design Organisation Approval | --- | --- | --- |
| Part 21, Subpart M | Repairs | --- | --- | --- |

## 1.3. ABBREVIATIONS

The following abbreviations are used in this Certification Memorandum:

| Abbreviation | Meaning |
|---|---|
| **AC** | **A**dvisory **C**ircular |
| **AMC** | **A**cceptable **M**eans of **C**ompliance |
| **CM** | **C**ertification **M**emorandum |
| **CAA** | **C**ivil **A**viation **A**uthority |
| **CS** | **C**ertification **S**pecification |
| **DOA** | **D**esign **O**rganisation **A**pproval |
| **EASA** | **E**uropean **A**viation **S**afety **A**gency |
| **FAA** | **F**ederal **A**viation **A**dministration |
| **FAR** | **F**ederal **A**viation **R**egulation |

| Abbreviation | Meaning |
|---|---|
| **OEM** | **O**perational **E**quipment **M**anufacturer |
| **PSE** | **P**rinciple **S**tructural **E**lement |
| **SRM** | **S**tructural **R**epair **M**anual |
| **STC** | **S**upplemental **T**ype **C**ertificate |
| **TC** | **T**ype **C**ertificate |
| **TCCA** | **T**ransport **C**anada **C**ivil **A**viation |
| **TD** | **T**ype **D**esign |

## 1.4. DEFINITIONS

The following definitions are used in this Certification Memorandum:

| Definition | Meaning |
|---|---|
| Adherend | A body that is held to another body, usually by an adhesive. A detail or part prepared for bonding. (SAE AIR 4844) |
| Adhesion | The state in which two surfaces are held together by interphase forces.<br>mechanical adhesion*, n*—adhesion between surfaces in which the adhesive holds the parts together by interlocking action.<br>specific adhesion*, n*—adhesion between surfaces which are held together by intermolecular forces of a chemical or physical nature[1].(ASTM D 907-8b) |
| Adhesive | A substance capable of holding two materials together by surface attachment. Adhesive can be in film, liquid, or paste form. In this context, the term is used to denote structural adhesives, i.e., those which create attachments capable of transmitting significant structural loads. (SAE AIR 4844) |
| Adhesion Failure | Separation of the adhesive-adherend interface due to inadequate bonding. |
| Bond | The adhesion of one surface to another, with or without the use of an adhesive as a bonding agent.[2] (CMH-17, Vol. 1, Chapter 1 rev. F) |
| Bonded Joint\Structure | See Structural Bonding (The term 'Bonded Joint\Structure' has typically been considered to mean Secondary Bonded structure. However, increasing diversity of material forms and processes has broadened the common meaning to include Co-bonding – see Figure 1 (CS 23.573(a)(5)). |

[1] Chemical adhesion is the primary goal for structural bonding discussed in this policy
[2] Uncured composite adherends may carry enough matrix material to complete adequate bonding when cured in place to form a bonded repair

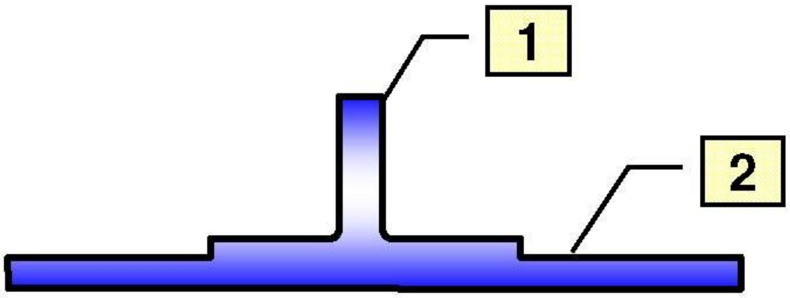
| Definition | Meaning |
|---|---|
| Bonded Repair | For the purposes of this Policy, Bonded Repair refers to repairs using Co-bonding or Secondary Bonding, as described in these definitions. This includes repairs that use uncured skins bonded over sandwich core. A repair means elimination of damage and/or restoration to an airworthy condition following initial release into service by the manufacturer. |
| Co-bonded Structure | Components bonded together during cure of one of the components. |
| Co-cured Structure | Uncured components cured together. Bonded repairs of co-cured structure are covered by this policy. |
| Cohesion | The state in which the constituents of a mass of material are held together by chemical and physical forces. (ASTM 907-8b) |
| Cohesive Failure | Rupture of a bonded assembly in which the separation appears visually to be in the adhesive or the adherend. (ASTM D 907-8b) |
| Composite Material | A combination of two or more materials (reinforcing elements, fillers, and composite matrix binder), differing in form or composition on a macro scale. The constituents retain their identities; that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. (See ISO 472) Composite materials are usually man-made and created to obtain properties that cannot be achieved by any of the components acting alone. (SAE AIR 4844) |
| Critical Structure | A load bearing structure/element whose integrity is essential in maintaining the overall flight safety of the aircraft.[3](AMC 20-29) |
| Critical Failure Mode | The failure mode most likely to compromise safety. |
| Cure | To develop the structural properties of an adhesive (or composite resin) by chemical reaction. (modified ASTM D 907-8b) |
| Debond | Same as disbond.[4] (AMC 20-29) |
| Disbond | An area within a bonded interface between two adherends in which an adhesion failure or separation has occurred.[5] 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 lamina in the finished laminate (in this case the term "delamination" is normally preferred). (AMC 20-29) |

[3] This definition was adopted for AMC 20-29 in order to ease the reading of the document, because there are differences between the definitions regarding the classification of structure across the certification specifications to which the AMC applies, i.e., CS-23, CS-25, CS-27, and CS-29. For example, PSEs are critical structures for Large Aeroplanes.
[4] "Debond" and "disbond" are used interchangeably throughout literature. The term "debond" may also apply to the process of deliberately separating joints, e.g., using heat guns, freezing etc., for the purposes of disassembly for access, repair etc.
[5]Adhesion failure or separation is usually unintended.

| Definition | Meaning |
|---|---|
| Initial Damage Mode | The first damage mode in the failure sequence, which may, or may not, be the same as the Critical Failure Mode. |
| Interim Damage Mode | Any damage mode(s), which may exist between Initial Damage Mode and Critical Failure Modes. |
| Primary Structure | The structure which carries flight, ground, or pressurization loads, and whose failure would reduce the structural integrity of the airplane. (AMC 20-29) |
| Principal Structural Element | Principal structural elements are those which contribute significantly to carrying flight, ground, and pressurisation loads, and whose failure could result in catastrophic failure of the aeroplane. (AMC 25.571 para.2) |
| Sandwich Constructions | Panels composed of a lightweight core material, such as honeycomb, foamed plastic, etc. to which two relatively thin, dense, high-strength or high-stiffness faces or skins are adherends. (See CMH-17 Volume 6) (SAE AIR 4844) |
| Secondary Bond | The joining together, by the process of adhesive bonding of <u>two or more</u> already-cured composite parts or metal parts, during which the only chemical or thermal reaction occurring is the curing of the adhesive itself.[6] (CMH-17 Vol. 1 Chapter 1 rev. F) |
| Structural Bonding | A structural joint created by the process of adhesive bonding, comprising of <u>one or more</u> previously-cured composite or metal parts (referred to as adherends). (AMC 20-29) Also, see the definition of "Co-cured Structure". |
| Weak Bond | A bond line with mechanical properties lower than expected, but without any possibility to detection using non-destructive inspection (NDI) procedures currently applied by industry. Such situations result from poor chemical bonding.[7] (AMC 20-29) |

[6] The word 'Secondary', historically used within the term 'Secondary Bonding', has been mistakenly considered to imply a lesser significance, e.g., in the sense of Secondary structure etc. For this reason, the intention of EASA and other Civil Aviation Authorities (CAAs) is to avoid using this term in regulatory text. When used, the understanding of the term Secondary Bond should be clarified with the user.

[7] Poor chemical bonding could be due to several contributing factors (e.g., material incompatibility, pre-bond surface contamination, use of out-of-date materials, environmental degradation of the adherends).

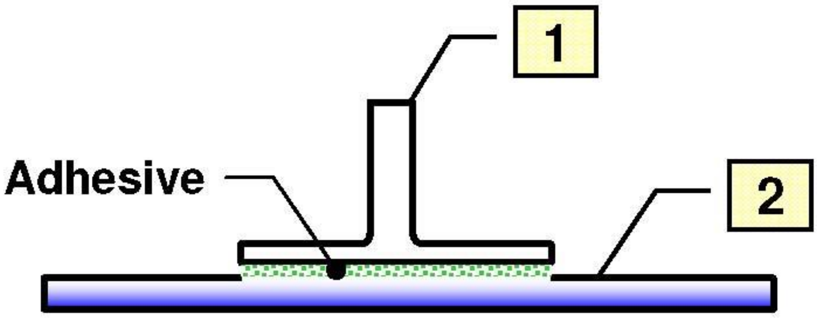



**Co-Curing:**

Components cured together

- Component 1 uncured
- Component 2 uncured

(may include additional adhesive and/or continuous structural plies common to both Components 1 and 2)




**Co-Bonding**

**(Structural Bonding):**

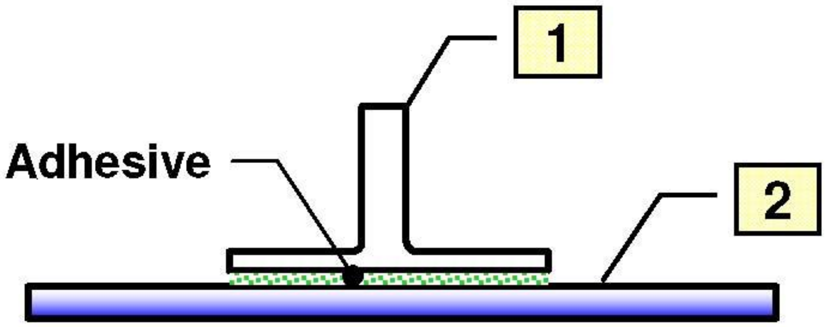
Components bonded together during cure of one of the components

- Component 1 cured*
- Component 2 uncured

or

- Component 1 uncured
- Component 2 cured*

* or metal
(may not necessarily include additional adhesive)




**Secondary Bonding**

**(Structural Bonding):**

Components bonded together with separate bonding operation

- Component 1 cured*
- Component 2 cured*

* or metal

**Figure 1. Bonded Structure – Definitions**

(Airbus – Composites Workshop Tokyo 2009)

# 2. BACKGROUND

The recent increase in implementation of bonding as a principal means of fabricating *Critical Structures* on large aeroplanes (e.g., pressure hull and wing box structure) increases the likelihood of bonding as a viable repair option. In the past, bonded repairs have generally been limited to less critical structure. These repairs have not always been successful. Unexpected repair failures, without obvious cause, have sometimes occurred. These "unsuccessful bonded repairs" have led to service delays and, in some cases, flight incidents. Such unexpected bond failures suggest that bonded repair of *Critical Structure* is a safety threat that needs to be managed.

Following several incidents related to bonded structure and reviewing AMC 20-29 and the FAA's AC 20-107B, Composite Aircraft Structure, the EASA and other CAAs consider it necessary to develop this policy statement to improve the quality of the guidance available on certification approaches for bonded repairs. Composite guidance (e.g., AMC 20-29) states that damage which lowers strength to approach Limit Load capability must be easily detectable and quickly found to maintain the desired safety levels. However, this is not obviously achieved if damage is not detectable (e.g., as a "Weak Bond" - sometimes called a "Kissing Bond" by NDI specialists) in a Bonded Repair.

A key technical problem associated with weak bonding is that environmental effects may continue to degrade the bond strength over time in an unpredictable manner. During the time leading to the point where complete bond failure occurs, there may be limited warning of a safety problem or existing damage state. However, the potential safety risk of not detecting a weak bond can be reduced by using baseline structural design concepts that have critical failure modes and damage growth sequences that are stable and well understood. For example, bonded repair to critical structure, which includes low safety margins and failure modes that are strongly affected by bonded repair failures, should be avoided. Furthermore, the use of some design features may improve the detection of a weakly bonded repair by virtue of the progressive growth of witness damages adjacent to the weakly bonded repair (e.g., obvious cracking local to the repair that remains arrested until the weak bond condition can be safely repaired).

In addition to the requirements necessitating an Ultimate Load capability demonstration, CS 23.573(a)(5) requires that in the event of bond failure, design features may be used to prevent disbond growth such that less than Ultimate Load, but greater than Limit Load capability is maintained. If "Weak Bond" damage exists in a bonded repair and remains undetected, the structure could be exposed to significantly less than Ultimate Load capability for long periods of time, which is unacceptable from a safety viewpoint.

The content of CS 23.573(a)(5) was not intended to address systematic bonding process problems that reduce the reliability of the repair. This point is reiterated by AMC 20-29 regarding Fatigue and Damage Tolerance considerations. However, it has become evident to the EASA and other CAAs that this is not clearly understood by some organisations supporting repair activities.

Good designs, qualified materials, proven processes, well-trained and experienced personnel, and existence of a structural substantiation database reduce the risks of disbonds or weak bonds. However, the risk of inadequate bond integrity is not fully mitigated, even if these aspects of good bonded repair practices are adopted; thus, the risk of operation in a less than *Ultimate Load Capable* condition must be further minimized. This is accomplished through a rigorous assessment validation that in the event of bond failure, residual strength capability will not fall below Limit Load.

The potential for older critical structure to include bonded repairs (particularly those not meeting the intent of this policy), which may have deteriorated due to environmental aging, should be considered within fleet leader and fleet sampling programs.

Repair design substantiation ensures the specific repair design details; including structural details, materials, processes, design criteria and supporting structural data (tests, analysis) have a high degree of reliability in meeting static strength, flutter, fatigue, damage tolerance, and other critical structural regulations. The information developed for complete bonded repair substantiation is not readily available to the engineering community operating in the field. Significant investment in resources, testing and analyses are needed in demonstrating compliance with the appropriate rules for structural substantiation of a given structure

FAA Policy Statement Number PS-ACE100-2005-10038 (Pages 7 and 13) associates many bond failures with invalid qualifications or insufficient quality control processes. It is well established that the mechanical performance of an adhesive bond is strongly affected by the rigor of the manufacturing processes used to produce it, and that many factors which degrade proper bonding can occur locally or over the entire bond surface. The processing steps required to achieve chemical adhesion are highly dependent on the base materials and adhesives used in the repair. This is the primary reason that only qualified bond materials and processes should be used. It must be noted that the need for material and process controls is not limited to the steps in the repair procedure itself. While appropriate surface preparation and cleanliness is an absolute requirement to achieve bond strength, the final strength is also strongly dependent on appropriate receiving, storing, and handling of materials prior to performing the repair. Work area environmental controls and cleanliness, and cure cycle accuracy are some of the many other factors that influence bond strength. Intuition should never override substantiated processes. For example, a rough surface does not necessarily yield a stronger bond. As a result, it is critically important to follow rigorously all materials and process steps defined in the substantiation database for the repair design.

In-service bonded repairs are typically performed less frequently than production bonding activities and often occur in less stabilized service environments. As a result, an in-service bonded repair is more likely to have material property variation[8] , which may alter the basis for repair substantiation and result in less than Ultimate Load capability in the repaired condition. Therefore, field conditions and the availability of experts in bonded in-service repairs, should be considered in developing supporting maintenance documents. Such considerations may yield more conservative (smaller) repair size limits for repairs performed in the field than may be allowed with bonded factory repairs.

The bonded repair should not exceed substantiated size limits. The bonded repair design and fabrication instructions should also outline the facilities, tooling, equipment, and technician skills required to complete the repair. Field repairs may need to be performed on the airplane using facilities, equipment, and tools adopted to mate with the assembled part. Special care must be taken to avoid contamination and to maintain the desired layup, bagging, and cure conditions.

The TC Holder Structural Repair Manual typically limits bonded repair size, often as a function of part location, based on their internal databases and access to field experiences. A SRM may be approved as part of the type design. Bonded repairs performed per an aircraft SRM must comply with all the processing limits, details, and limitations. The bonded repair would otherwise require a specific approval substantiating deviations or new processes.

Reverse engineering practices, as often applied on metallic structure, or even when used to generate design data through conservative assumptions, will generally not equip the designer with a full understanding of the knowledge basis necessary to expand bonded repair size limits defined in the SRM. Therefore, it cannot be asserted that structural substantiation has been accomplished for the "reversed-engineered" design or that a safe product will result, unless additional data is generated to address the considerations documented in this policy.

In some cases, it has been argued that a part utilizing bonding can be remanufactured well beyond published relevant bonded repair size limits using TC Holder specified materials, processes, tooling, and structural details without additional data since it is considered to be substantiated by the original type certification. Unless assistance has been provided by the TC Holder, it is unlikely that this process can be safely accomplished by a 145 organisation without further substantiating data being developed.

[8] Bonded Repair of Aircraft Composite Sandwich Structures, DOT/FAA/AR-03/74 (Fig.24)

The effects of exposure to in-service loads and environmental aging should also be considered in the substantiation of repairs. Some recent research results with cured composite materials show reduced repair bond strength, which may be linked to irreversible environmental and mechanical load history.

Further to the text above, additional considerations may be needed for some structures to ensure that the bonded repair size limit is properly defined. For example,

- comprehensive damage characterization may be needed prior to repair to determine the full extent of damage, including significant areas of hidden damage, depending on the part configuration and the damaging event.
- some repaired components may require a full fatigue and damage tolerance assessment. The effect of a failed bonded repair should be considered when evaluating the adjacent structure in a multi-load path design.
- for structural repairs subject to cabin pressurization loads where partial or complete failure of the repair could lead to pressure loss, rapid decompression should be considered within the structural evaluations.

Additional considerations may also need to be applied to structures not typically considered PSE or Primary Structure, but for which repair failure could result in a significant reduction in safety.

- bonded repairs to composite and metal engine structures should consider whether the failed repair can be ingested and damage engine parts.
- repairs to large fairings, which may depart the aircraft, if failed, and impact downstream critical structure require other consideration.

Such evaluations will require engineering judgment. The EASA should be consulted early in the process whenever additional substantiation data is needed to extend existing repair size limits.

## 2.1. EXISTING REQUIREMENTS AND AMC

Structure, including repairs, satisfy the requirements. The following requirements are of particular relevance to the design of bonded repairs which are to be implemented in a service environment. This requires appropriate understanding by the DOA (TC or non-TC holder) regarding design and repair sizing. It also requires the understanding of the maintenance organisation executing the repairs as regards to limitations associated with the interpretation of Part 145 with respect to the scope of fabrication.

### 2.1.1. CS 2x.603 Materials (For composite materials see AMC 20-29)

*'The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must -*

*…*

*(b) Conform to approved specifications, that ensure their having the strength and other properties assumed in the design data…*

*(c) Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.'*

### 2.1.2. AMC 20-29 'Composite Aircraft Structure'

AMC 20-29 develops discussion relating to the requirements, including the key requirements below, as applicable to composite structure and para. 6.c. specifically introduces the subject of bonded structures and the developed use of CS 23.573(a)(5) for the other CSs.

Para. 10 addresses 'Continued Airworthiness' and states:

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

Para. 10.c.(1) makes clear that substantiation of the bonded repairs may require data beyond that of the baseline structure stating:

*'…substantiation data will generally be needed for damage types and sizes not previously considered in design development'*

and

*'Bonded repair is subjected to the same structural bonding considerations as the base design*

*(refer to paragraph 6.c).'*

Furthermore, Para. 8.a.(2)(c) states:

*<u>'For any damage size that reduces load capability below ultimate, the component is either</u>*

*<u>repaired to restore ultimate load capability or replaced.'</u>*

### 2.1.3. CS 2x.605 Fabrication Methods

*'(a) The methods of fabrication used must produce a consistently sound structure. If a fabrication process (**such as gluing**, spot welding, or heat treating) requires close control to reach this objective, the process must be performed under an approved process specification.*

*(b) Each new aircraft fabrication method must be substantiated by a test programme.'*

### 2.1.4. CS 2x.613 Material Strength Properties and Material design Values

*'(a) Material strength properties must be based on enough tests of material meeting approved specifications to establish design values on a statistical basis.*

*(b) Material design values must be chosen to minimise the probability of structural failures due to material variability…'*

### 2.1.5. PART 21 Subpart M, 21.A.433 Repair Design

*'(a) The applicant for approval of a repair design shall:*

*1. demonstrate compliance with the type-certification basis…'*

Noting that the Type Design consists, Part 21.A.31, of 'drawings and specifications', including 'Information on materials and processes and on methods of manufacture and assembly of the product necessary to ensure the conformity of the product', then the potential for a bonded repair process to change the TD should be recognised. Therefore, demonstrating compliance with the TC basis, including all processes is important.

### 2.1.6. AMC 145.A.42(c) Acceptance of Components

This CM is focused on Primary Structures and PSEs. However, it also recognises that some structures not typically considered to satisfy the definitions of Primary Structures and PSEs could reduce the level of safety should a repair fail, e.g. large fairings which could separate and impact other structure or be ingested by engines. These may require further consideration. Therefore, AMC 145.A.42(c) is referenced in this CM in order to support the decision process regarding interpretation of para. 7, either within a Part 145 organisation or as part of a non-TC holder DOA process, e.g. Part 21 Subpart J & Subpart M etc.

*'7. Examples of fabrication under the scope of an Part-145 approval can include but are not limited to the following:*

*…*

*b) Fabrication of secondary structural elements and skin panels.*

*…*

*Note: It is not acceptable to fabricate any item to pattern unless an engineering drawing of the item is produced which includes any necessary fabrication processes and which is acceptable to the competent authority.*

*8. Where a TC-holder or an approved production organisation is prepared to make available complete data which is not referred to in aircraft manuals or service bulletins but provides manufacturing drawings for items specified in parts lists, the fabrication of these items is not considered to be within the scope of an approval unless agreed otherwise by the competent authority in accordance with a procedure specified in the exposition.'*

# 3. EASA CERTIFICATION POLICY

## 3.1. EASA Policy

Bonded repairs must meet the appropriate airworthiness requirements for the structure they are designed to cover, including material and process qualification, static strength (Ultimate Load), and fatigue and damage tolerance. Bonded repairs to critical structure should also meet the conditions specified in this policy statement.

Bonded repairs may not require size limits for structure where there is no safety risk in the event of repair failure. In contrast, repair size limits may be restrictive for critical structures addressed by this policy.

The maximum size and other limits for a bonded repair depend on the limitations inherent in the design to be repaired. There may also be repair size limits or other constraints associated with the substantiating data used to meet the appropriate rules. These may include:

1. Repair processes that produce a consistently sound structure and critical fabrication processes must be performed using qualified repair materials and process specifications. Repair designs must be approved in accordance with Part 21, and must be performed and inspected by properly trained/qualified individuals with suitable experience.

2. Repair designs must have structural substantiation based on tests or analyses supported by tests. The bonded repair must be shown to be capable of withstanding ultimate static loads and be shown to retain the required residual strength, as defined in the applicable CSs, which include, but are not limited to;

   - Fatigue and damage tolerance (CS 23.573, 25.571, 27.573 & 29.573)
   - Static and dynamic strength requirements, (CS 2x.305 & 2x.307)
   - Material and fabrications specification requirements, (CS 2x,603 & 2x,605)
   - A requirement for statistical material design values, (CS 2x.613)
   - Flutter protection, and (CS 2x.629)
   - Lightning protection. (CS 2x.954 & 2x.981)

3. The data supporting the bonded repair should include inspections that are capable of detecting complete or partial failure (within arresting design features) of the bond line. Inspection thresholds and intervals should be set that consider criticality of the structure and the magnitude of the residual strength of the failed repair (i.e., a failed repair which could result in a residual strength near Limit Load is recommended to be inspected with increased frequency).

All critical structure will have a repair size limit *no* larger than a size that allows Limit Load strength to be achieved with the repair failed or failed within constraints of the arresting design features (in the repair or base structure). This approach is needed to ensure Limit Load capability in the event of bonded repair failures such as "weak bonds", which result from rare processing mistakes or other problems in combination with the service environment that cannot be ruled out through a threat assessment.

As noted in item 2 from above, bonded repairs must be designed to be damage tolerant in order to preclude catastrophic failure due to fatigue, corrosion, manufacturing defects or accidental damage throughout the operational life of the aircraft. Manufacturing defects, which can be detected with available inspection methods (i.e., porosity, disbonds and other anomalies) must be controlled within inspectable limits and included in the damage tolerance assessment as appropriate. Per item one above, the design and process specifications should make manufacturing defects for which inspection methods are not available, (i.e., weak bonds) extremely rare. Regardless, the design of the repair still must account for these rare events and be considered in the damage tolerance evaluation. The regulatory considerations for accounting for these rare events may be addressed as follows:

- When complying with CS 23.573(a)(5)(i), all CS-23 critical structure must have a bonded repair size limit no larger than a size that allows limit load strength [per loads defined in 23.573 (a)(3)] to be achieved with the repair failed or failed within constraints of the arresting design features (in the repair or base structure).
- When complying with CS 25.571, 27.573 and 29.573, all CS-25 PSE and CS-27 and CS-29 critical structures have a minimum required residual strength of limit load (as defined in the regulations for each type of aircraft) for all assumed detectable damage types. Limiting the bonded repair size to sustain the minimum required loads with the bond failed or failed within constraints of the arresting design features (in the repair or base structure) is an acceptable approach to address potential weak bonds.

AMC 20-29 provides a further description of the bonded structure or repair qualification, quality controls and reliable procedures needed to ensure weak bonds are extremely rare. The bonded repair size limits are first constrained by the data collected in establishing sound fabrication processes and substantiating the design. In addition, the bonded repair may be no larger than needed in demonstrating residual strength for a failed repair. All other approaches applied in establishing bonded repair size limits must have approved substantiating data, inspections or other procedures, as necessary, to prevent catastrophic failure.

Residual strength requirements with the repair failed should be shown by tests or analysis supported by tests. Some structure may be shown to have Limit Load capability, even with a very large failed repair. If significant changes in structural stiffness and/or geometry result from the failed repair, analysis for flutter and other aeroelastic instabilities should be performed to ensure the failed repair does not lead to other flight safety issues.

Documentation on all repairs should 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. It also helps ensure the associated data, including repair design and process details, structural substantiation evidence, and inspection procedures, are available to those evaluating airworthiness. Any failed bonded metal or composite repairs should be reported through the normal incident or accident reporting process (e.g., failure, malfunction, or defect reports required by Part 21.A.3 or service difficulty reports required by Part 145.A.60 or Part M.A.202).

The inspection of bonded repairs, including the specified inspection methods, interval and detection criteria, should be defined based on substantiating tests, analyses, trials, and other safety risk mitigation procedures.

## 3.2. WHO THIS CERTIFICATION MEMORANDUM AFFECTS

This Certification Memorandum affects applicants, for a repair design approval who need to show compliance with CS 2x.603 Materials and associated AMC 20-29. It is also of background interest to those showing compliance with Part 145, e.g., AMC 145.A.42 para.7.

# 4. REMARKS

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **20th of October 2014**. 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 Planning 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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