EASA Composite Materials Safety Strategy

- Sandwich Structures CM

- Shared Database – NCAMP CM

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EASA Rotorcraft Structures Workshop

February 2019, Koeln

Your safety is our mission.

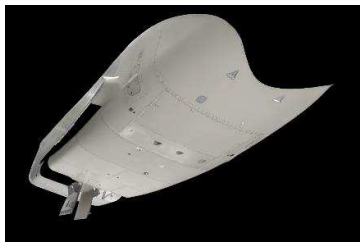
An agency of the European Union

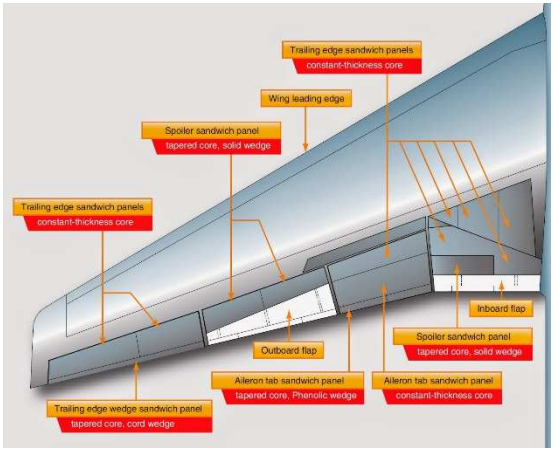
EASA Composite Materials Safety Strategy

Sandwich Materials/Structures

- established successful use with many sandwich materials…

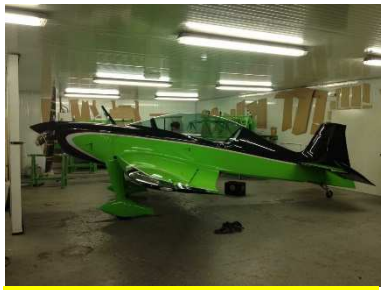
- less critical structures, e.g. fairings, radomes etc





- Primary Structures, e.g. control surfaces

- PSEs….and some monocoque structures



sandwich wing covers and fuselage

sandwich rotor blades and monocoque tail boom and blades

sandwich monocoque fuselage

Sandwich* Materials/Structures

- very broad range of constituent materials, configurations, and applications

Sandwich Constructions (SAE AIR 4844):

Panels composed of a lightweight core material, such as honeycomb, foamed plastic, etc., to which two relatively thin, dense, high-strength, high-stiffness faces or skins are adhered.

- mixed structural functions (skin and core)
- typically bonded (e.g. structurally bonded)

…a structure or a material?

sandwich structure… a bonded structure…
… need to delete misleading example
… encourages use of monocoque sandwich
… structure without back-up features
… **define sandwich structure by its most limiting bonding concept… typically co-bonded or 'secondary' bonded, not co-cured**…

*Note: identified as 'co-cured' example in AR-96/75 and AC29 2C MG8:

'(7) **COCURE**. The process of curing several different materials in a single step. Examples include …**sandwich structure** or skins with integrally molded fittings.'

This needs review…may not be helpful/appropriate to our discussion….sandwich is carrying primary load through an adhesive between features with different functions, some already cured,… therefore co-bonded/'secondary bonded', would seem to be more appropriate

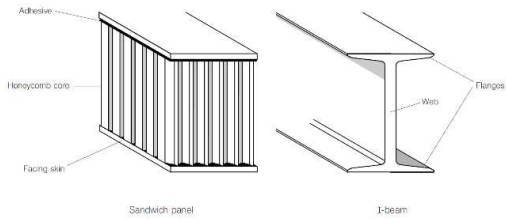


Figure 1 shows the construction of a sandwich panel compared to an I beam.

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Sandwich Materials/Structures

- many competing damage modes,
  - some not readily detectable
  - Boundary Conditions important

- some uncertainty wrt damage metrics..

'…it was concluded that residual indentation depth is not a reliable indicator of impact damage; rather, the planar damage size better reflects the residual strength degradation in sandwich panels.'*

*DOT/FAA/AR-02/121 Guidelines for Analysis, Testing, and Non-destructive Inspection of Impact-Damaged Composite Sandwich Structures

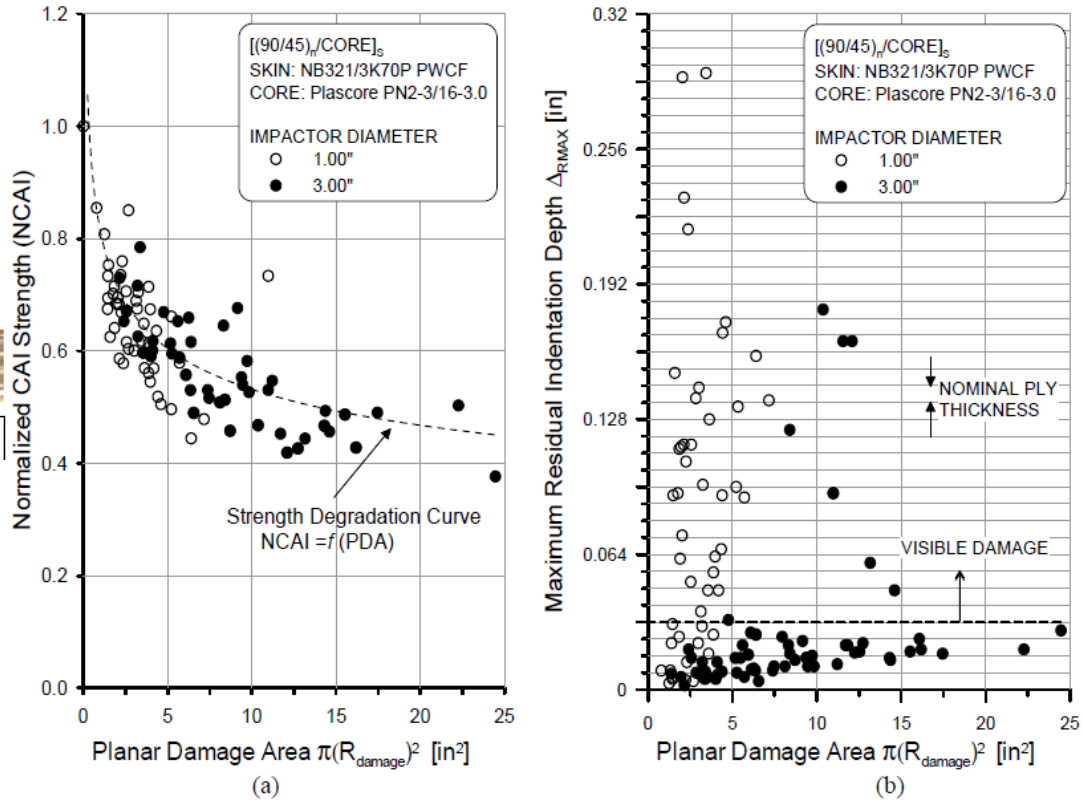
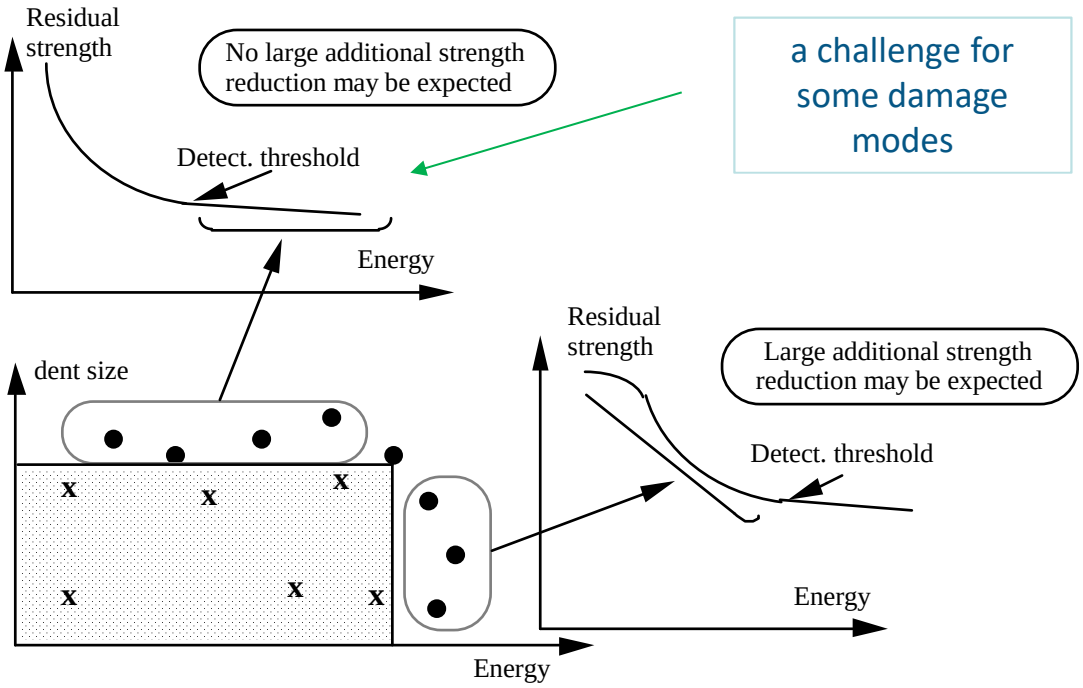


FIGURE 2-10. (a) NORMALIZED RESIDUAL STRENGTH FOR $[(90/45)n/CORE]_s$ (n=1,2,3)* SANDWICH PANELS WITH HONEYCOMB CORE (3/8″ AND 3/4″ THICK) AND (b) VARIATION OF MAXIMUM RESIDUAL INDENTATION DEPTH WITH PLANAR DAMAGE AREA FOR THE SANDWICH PANELS

Sandwich Materials/Structures – Residual Strength

- ideally, detect damage in a configuration which demonstrates no damage growth and has a useful RS (flat part of the curve)



x damages addressed for meeting § 25 305 requirements

CMH-17 Vol.3 Rev. G Chpt.12

● **additional** damages to be addressed for § 25 571 requirements

AMC 20-29 Para.8. **PROOF OF STRUCTURE - FATIGUE AND DAMAGE TOLERANCE**

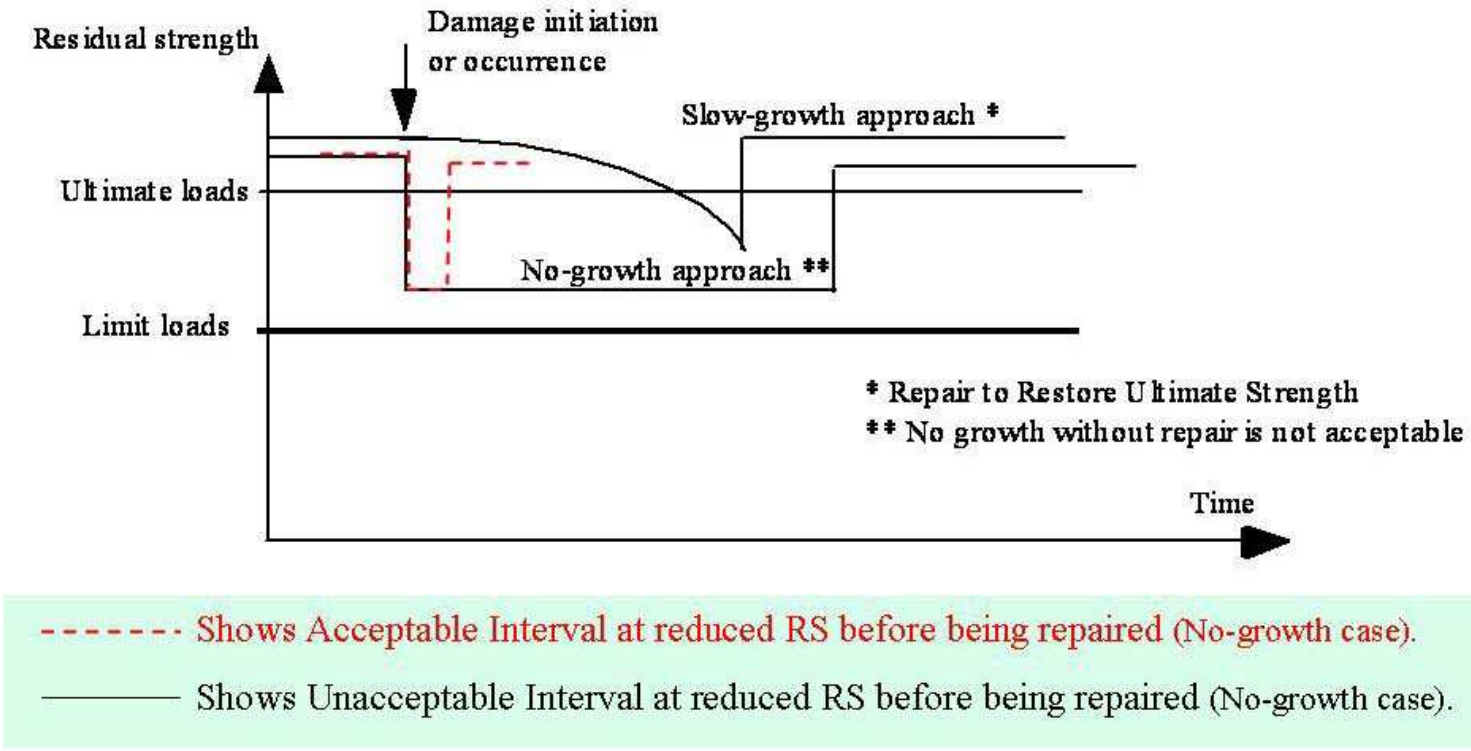


Figure 4 - Schematic diagram of residual strength illustrating that significant accidental damage with “no-growth” should not be left in the structure without repair for a long time.

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CS29.573: **Damage tolerance and fatigue evaluation of composite rotorcraft structures**:

similar intent other CSs

'(d) Damage Tolerance Evaluation…

(2) The damage tolerance evaluation must include PSEs of the airframe, main and tail rotor drive systems, main and tail rotor blades and hubs, rotor controls, fixed and movable control surfaces, engine and transmission mountings, landing gear, and any other detail design points or parts whose failure or detachment could prevent continued safe flight and landing…

(iv) A Threat Assessment for all structure being evaluated that specifies the locations, types, and sizes of damage, considering fatigue, environmental effects, intrinsic and discrete flaws, and impact or other accidental damage (including the discrete source of the accidental damage) that may occur during manufacture or operation;…'

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Sandwich Materials - Bonded Structures:

Disbond or delamination:

- **a disbond/weak bond/delamination exists**
- **< UL capability** (large damage/disbond, critical location)
- **damage/defect remains undetected**
- **load event > Residual Strength capability** (>LL)

- all of these can occur, but typically not together…..

- most events not significant safety issue*
  applications have not been significant

*variable quality data

- unclear if disbond is cause or witness (either situation suggests poor process - unacceptable)

- **need to improve forensics and taxonomy**

1 incident 10^6 hrs
1 serious incident 10^8 /10^9 hrs
No fatal accidents
(CAA-UK MOR & fleet data only)

1 serious incident/accident
>10^8 hrs
- EASA database

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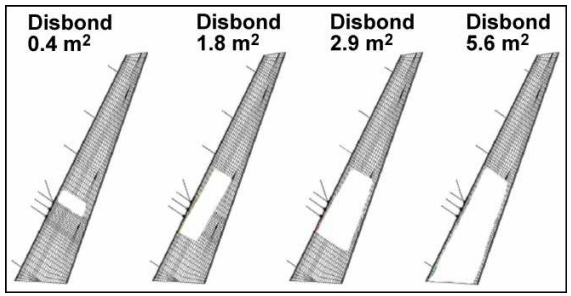
Although difficult to generalise, some configuration/application grouping is possible for investigation, e.g. thin skin sandwich structures (baseline and repairs) subject to Ground-Air-Ground (GAG) cycles …

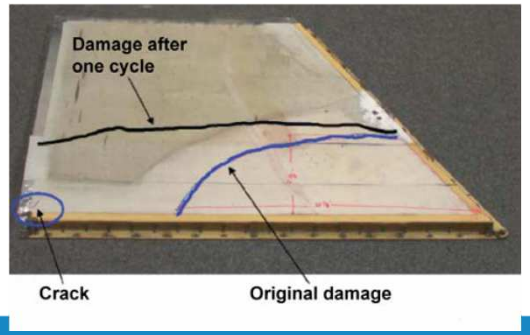
- extensive Airbus work to understand GAG cycle

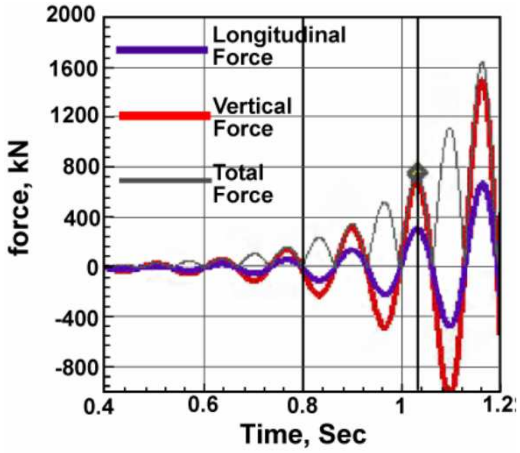
(Airbus: Roland Thevenin, Ralph Hilgers e.g. presentations CMH-17 26-28/9/11 Delft)

- icw CMH-17 Disbond/Delamination Task Group

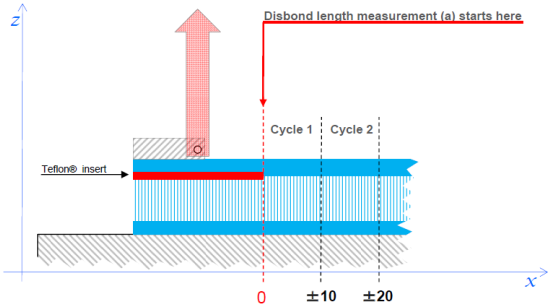
(Airbus: NASA: Ronald Krueger)



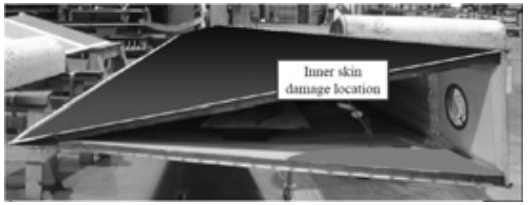




Load response – from time domain flutter analysis



A good example of industry sharing information in order to improve safety …



typical existing fleet structure configurations

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However, some incidents and '**lessons learned**' associated with a broader range of material configurations and applications (beyond thin skin/GAG control surfaces) justify further consideration and possible development of improved guidance material

/Q/ Is monocoque sandwich structure appropriate for some 'critical single load path' applications, e.g. pressure hull, tail booms etc?

… single critical load path DT discussion now part of current ARAC DT Tasking

/Q/ If so, then what design criteria should be used?

Some useful references regarding robust sandwich design can be found at:

- CMH-17 Vol.6 (and other references) identifies many potential damage modes

- B. Moitre, A. Marzano (ENAC) - EASA Bonded Structure Meeting June 2013 - 'lessons learned' regarding monocoque sandwich structures

- A. Engleder (Airbus Helicopters, ex- EC) – CMH-17 Meeting Boston August 2012 - several rotorcraft configuration specific monocoque sandwich structure damage modes discussed

- D. Wernert (Textron, ex-HBC) – EASA Bonded Structure Meeting June 2013 - practical robust monocoque sandwich structure design

… useful safety messages

Example*:

Suggested regulatory approach? *… includes extensive exploration of impact threat…

TASK 1: DAMAGE FORMATION IN SANDWICH STRUCTURES SUBJECTED TO LOW-VELOCITY IMPACT

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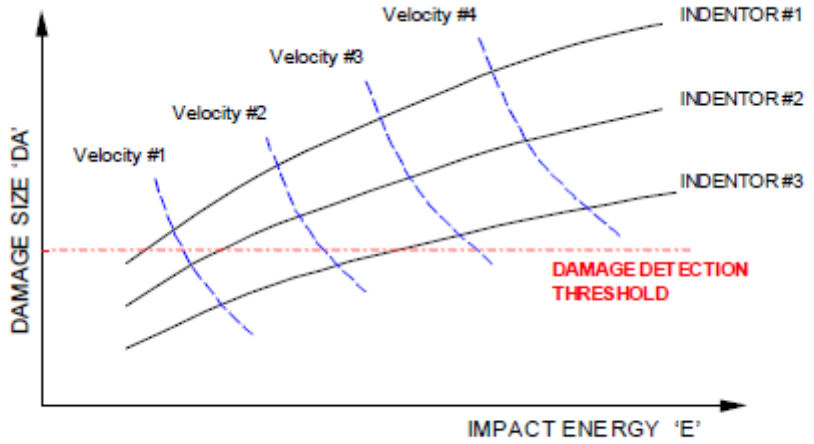


FIGURE 25. TYPICAL PLOTS EXPECTED FROM THE EXPERIMENTAL PROGRAM

* e.g. DOT/FAA/AR-99/49 Review of Damage Tolerance of Composite Sandwich Airframe Structures

EASA Composite Materials Safety Strategy

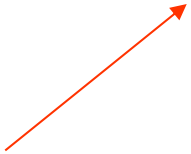
EASA Composite Materials Safety Strategy – related actions:

1/ EASA CM – S – 010 Issue 1 'Composite Materials – The Safe Design and Use of Monocoque Sandwich Structures in Principal Structural Element Applications'
https://www.easa.europa.eu/sites/default/files/dfu/CM-S-010%20Issue%2001.pdf

Basic messages for PSEs:

Multi-load path Sandwich Structures:

– robust interpretation of existing design, production, and ICA practices required,
e.g. established in-house practices, DOT/FAA/AR-99/49 Review of Damage Tolerance of Composite Sandwich Airframe Structures etc



not new… might benefit from some standardisation

not new… highlights challenging issues experienced in-service and development

EASA Composite Materials Safety Strategy

EASA Composite Materials Safety Strategy – related actions:

Monocoque Single-load path Sandwich Structures:

– as per multi-load path sandwich structures

+

- other mitigating factors*, e.g.

e.g. return to service with potentially catastrophic undetectable failure modes, following Cat.5 incident, to be avoided…

use of higher density/expanded core… typically part of corrective actions…

- lower strains?

- A-basis data (static and fatigue) **?**

- appropriate/more robust core density selection criteria?

- post incident inspection practices/methods?

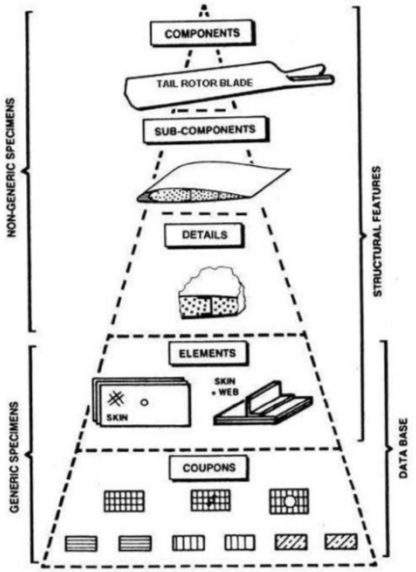
* standardised details to be developed in later CM revision

Note: FAA Sandwich AC in development

Shared Databases:

Composite Shared Databases:

- limited established sharing of composite specs and compositions – unlike metals (proprietary data etc)
- need for complete test pyramid when the same material is used by different organisations?
- ‘engineering properties’ result from material, process, and ‘configuration detail’
- ‘configuration detail’ data unlikely to be applicable between different organisations designs, however potential value in sharing base pyramid work, if the same material is used…



Regulators unlikely to be confident in higher pyramid design data if simple base pyramid properties cannot be consistently produced following standard procedures and test methods

Potentially more important for GA and Rotorcraft, noting typically limited mid-pyramid test data available, e.g. due to component definition/boundary condition validity, limited high pyramid load case testing (for GA)….. and COST!

Composite Shared Databases: History – Not New

National Center for Advanced Materials Performance (NCAMP)*:

- open group of global organisations (subject to following Standard Operating Procedures (SOPs) and meeting other conditions)
- base pyramid composite specific data sharing (simple flat coupons etc)
- two main levels of activity:
  - users of data for materials in the existing NCAMP database (show equivalence using a reduced dataset)
  - new material contributors
- follow Standard Operating Procedures (SOPs)
- independent checking of data (panels tested etc)

Note: CMH-17 NCAMP Tutorial planned

* Note: Originally Advanced General Aviation Transport Experiments (AGATE), formed in 1990s intended to support GA. However, evolved into NCAMP, currently populated by prepregs and CS25 supplier organisations. However, may become more relevant to GA again as more prepreg is used. Also seeing developing us in Rotorcraft applications.

EASA Composite Materials Safety Strategy

Integration with CMH-17 in progress – data publication

SOPs continue to evolve

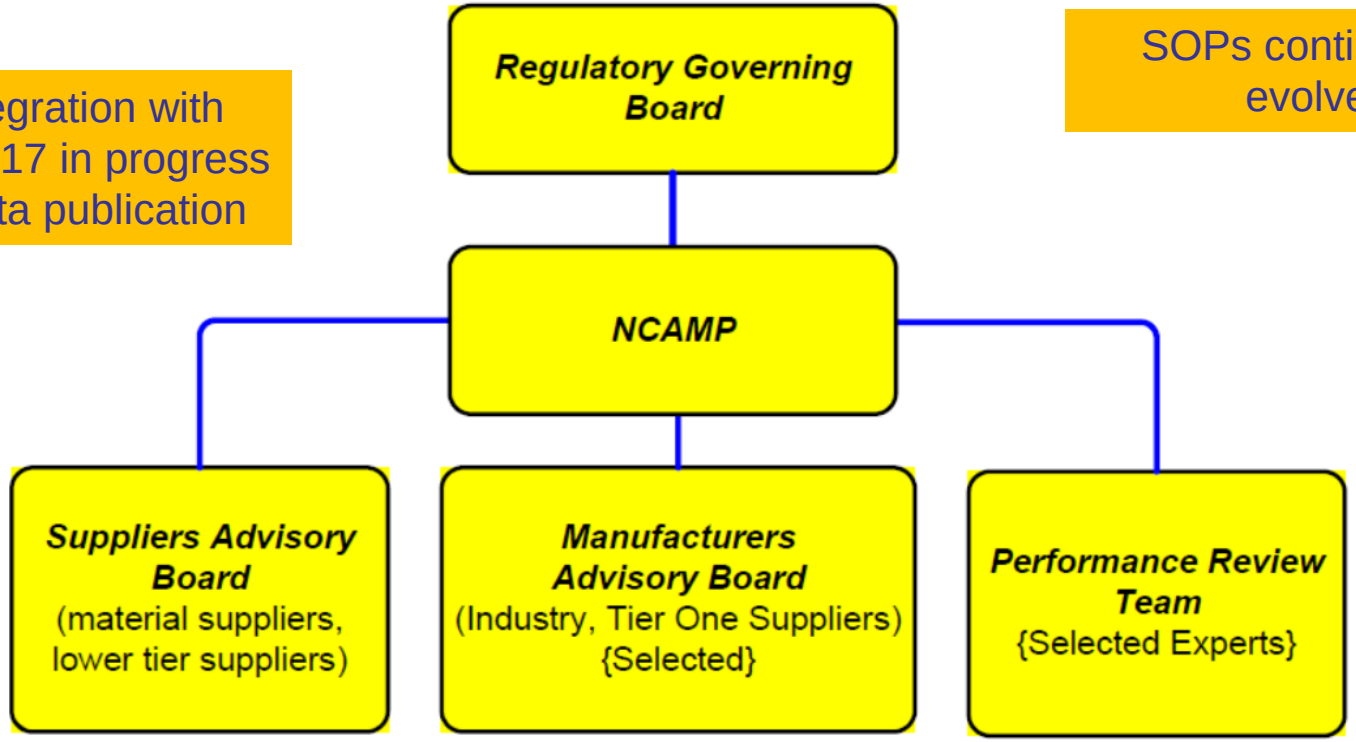


Figure 1. NCAMP Organizational Structure

Composite Shared Databases:

NCAMP: EASA CM – S – 004 Issue 01 'Composite Materials – Shared Databases, Acceptance of Composite Specifications and Design Values Developed using the NCAMP Process'

For organisations choosing to use NCAMP, EASA aacpts data, subject to review:

- project Validations, e.g. for EASA Validation of FAA products

- EASA product Certification, **when the applicant has fully engaged with the NCAMP processes***, as acceptable to NCAMP and EASA

small organisation issues recognised… limited resource, but need to maintain independence and satisfy 21A.239(b) and CVE functions: https://www.easa.europa.eu/faq/20110

* Standard Operating Procedures (SOPs)

Improve integration of NCAMP SOP identified functionaries in DOA/NAA activities:

Authorised Engineering Representative (NCAMP AER*):

…responsible for (1) reviewing and recommending acceptance of documents such as test plans and specs (2) witnessing specimen testing, and (3) accepting test data…

Proposed: EASA CVE (with appropriate composites experience identified in capabilities)

- **direct AER function or finding appropriate AER**

*** supported by/or initially EASA/NAA (review, but not recommend)**

Authorised Inspection Representative (NCAMP AIR*):

…responsible for inspection and verification of test panels and specimens

Proposed: EASA CVE (with appropriate composites experience identified in capabilities, QA important)

- **direct AIR function or finding appropriate AIR**

*** CVE not to be both AIR and AER on same project!**

* will need to also obtain NCAMP acceptance

Composite Shared Databases:

Summary:

- movement from ‘prescriptive’ to ‘performance’ based regulation means that industry will increasingly rely upon its own activities to be satisfied that a ‘level playing field’ is being maintained, e.g. use of standardisation bodies, databases etc
- many shared databases exist globally, operating either within or between organisations and functioning to different levels in the test pyramid, but few global databases
- EASA will work with the European GA and Rotorcraft industries to support the most efficient development and use of databases*… smoother integration into DOA structure
- NCAMP
  - first thermoplastic due to be included (approx. 50 thermosets already established, or in progress)
  - expansion to include non-metallic Additive Manufacturing expected soon (interiors/low criticality parts)
- EASA CM – S – 004 likely to be revised to provide more clarification

* Note: potential for complementary database utilisation

EASA Composite Materials Safety Strategy

QUESTIONS?

/Q/ Question to the European Rotorcraft Industry: Is there interest in forming a European Composite Rotorcraft Group?

If so, please contact me: simon.waite@easa.europa.eu

Support Slides – Sandwich Structures

EASA Composite Materials Safety Agenda

CMH-17 Disbond/Delamination TG:

'Working Meeting + future direction'

Koeln 19-20th September 2017*

Day 1- Honeycomb General & EASA DoSS Project

- 08:00 – 08:30 Opening (Simon Waite and Larry Ilcewicz)
- 08:30 – 09:00 Airbus (Chantal Fualdes & Roland Müller)
- 09:00 – 09:30 Fokker Experience with Sandwich Structures, Metal, Thermoset and Thermoplastic (Andries Buitenhuis)
- 09:30 – 09:45 Coffee Break
- 09:45 – 10:15 EASA DoSS Project – General Overview (Christian Berggreen)
- 10:15 – 10:30 Aerospace Needs & Boundaries (Ralf Hilgers)
- 10:30 – 11:15 WP2 Honeycomb Sandwich Property Measurements (TU-Dresden, Ralf Schäuble)
- 11:15 – 12:30 WP1 Coupon SCB Tests (Ralf Schäuble)
- 12:30 – 13:30 Lunch
- 13:30 – 14:00 WP1 Coupon SCB Tests (Yannick Albertone)
- 14:00 – 14:30 WP1 Coupon SCB Tests - Fatigue (Sönke Fimmen)
- 14:30 – 15:30 WP1 Coupon DCB-UBM Tests – Mode-I/Mixed-mode Static & Fatigue (Vishnu Saseendran)
- 15:30 – 16:30 WP2 Analysis of the SCB and DCB-UBM test specimens (Vishnu Saseendran)
- 16:30 – 17:00 EASA Doss Project Discussion

*following EASA Sandwich Structure Meeting 18/10/16

http://www.easa.europa.eu/newsroom-and-events/events/easafaa-sandwich-structure-workshop

EASA Composite Materials Safety
Agenda

CMH-17 Disbond/Delamination TG:

'Working Meeting + future direction'

Koeln 19-20th September 2017*

Day 2 – Working Group Review Test & Analysis

- 08:00 – 08:20 Sandwich Disbond Initiative – Status and Priorities (Larry Ilcewicz)
- 08:20 – 09:45 Road Map Update & Discussion (Ronald Krueger)
- 09:45 – 10:00 Coffee Break
- 10:00 – 11:00 ASTM Standard - Update & Discussion (Dan Adams, Ronald Krueger)
- 11:00 – 12:30 U.S. Led Follow-on Building Block Activity (Adams, Seneviratne)
- 12:30 – 13:30 Lunch
- 13:30 – 14:30 Analysis Round Robin Phase 0 results (Arash Farshidi)
- 14:30 – 15:00 Discuss & Launch next Analysis RR-Phase (Christian Berggreen)
- 15:00 – 16:00 Study of Damage Modes in Lightweight Sandwich Structures Using Analysis and Testing – Overview of FAA project (Krueger, Chen)
- 16:00 – 17:00 Group Open Points & Wrap-Up

EASA Composite Materials Safety

baseline structures **and repairs**

Example: Key Specification applicable to baseline structure **and repairs**….

CS25.571: ***Damage-tolerance & fatigue evaluation of structure***

Note: Recent Amendments CS25 amdt.19

'(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, manufacturing defects, environmental deterioration, or accidental damage will avoided throughout the operational life of the aeroplane…'

'(3)…..inspections or other procedures must be established as necessary to prevent catastrophic failure, and must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529'

Does not need to be visual,
…or an inspection
Note: 80-90% of inspections are visual
ref. also CS25.611

need to find, define, and bound damage…

Reminder PSE definition:

CS2x.571 (Amdt.19) Appendix 5 para.b*:*

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

Not limited to fatigue issues…. also consider ED and AD

… particularly important for sandwich structure

EASA Composite Materials Safety Strategy

- related discussion already started…

- CMH-17 Vol.6 (and other references) identifies many potential damage modes

- for some configurations, other than thin skin GAG configurations, organisations have shared ‘lessons learned’, e.g.

- B. Moitre, A. Marzano (ENAC) - EASA Bonded Structure Meeting June 2013
  - ‘lessons learned’ regarding monocoque sandwich structures

- A. Engleder (Airbus Helicopters, ex- EC) – CMH-17 Meeting Boston August 2012
  - several rotorcraft configuration specific monocoque sandwich structure damage modes

- D. Wernert (Textron, ex-HBC) – EASA Bonded Structure Meeting June 2013
  - practical robust monocoque sandwich structure design

- can we produce useful generic guidance for such configurations?

… useful safety messages

EASA Composite Materials Safety Strategy

EASA Composite Materials Safety Strategy – related actions:

2/ R&D – intended to continue development in understanding of the current thin skin GAG issue and also to initiate thoughts for the other configurations:

https://www.easa.europa.eu/the-agency/procurement/calls-for-tender/easa2016hvp14

e.g. many existing basic tests methods available addressing many damage modes at base of test pyramid.
Higher pyramid configuration mixed mode baseline test necessary?
Standard to test more load cases?

EASA R&D 'Task 3':

- further develop SCB standard and Mode 1 thin skin control surface GAG work (existing fleet)?

- identify and define dominant failure mode for other incidents, configurations, e.g. rotorcraft?

identify address priority issue at engineering/certification level…

- develop Mode 2 or 3 test standard?

- develop robust core density selection criteria standard?

Future EU project?

- develop post incident inspection practices/methods?

Support Slides – Shared Databases

Composite Shared Databases: History – Not New

AFF/HFF*: (to be discussed by Marcus Basien)

- long established closed group of organisations (until recently**)
- functions and data sharing not limited to composites
- composites - shared base pyramid data + some higher level details
- wet lay-up and bonded joints

* AFF - Arbeitskreis Faserverbund Flugzeugbau, publishes a manual for composite aircraft called HFF Handbuch Faserverbund Flugzeuge.

** recent project development with AFF/HFF beyond Germany to be presented by Philipp Steinbach (Game Composites)

EASA CM – Terms of Reference Reminder

(as stated on the CM cover page!):

…intended to provide guidance on a particular subject and, as non-binding material, may provide **complementary information**

… must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM).

… not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

Composite Shared Databases:

NCAMP: EASA CM – S – 004 Issue 01 'Composite Materials – Shared Databases, Acceptance of Composite Specifications and Design Values Developed using the NCAMP Process'

'Subject to appropriate European Industry interest being expressed to EASA, EASA may consider further development of the harmonisation process…

e.g. **the independent panel testing by a recognised European test facility and/or data review could be completed within Europe as part of a harmonised process**.

Note: Needs to be improved to further reduce transport costs etc… differences between FAA and EASA conformity witnessing requirements need to be addressed. One possibility is development of independent test houses to complete independent panel testing and review steps

Composite Shared Databases:

NCAMP SOPs and European Functionaries:

Authorised Engineering Representative (AER):

2.5.2 Authorized Engineering Representative (NCAMP AER)

The NCAMP AER is an individual qualified to conduct independent/un-bias engineering functions. The NCAMP AER is typically responsible for (1) reviewing and recommending acceptance of documents such as test plans and specifications, (2) witnessing specimen testing, and (3) accepting test data. Individuals desiring to hold this position must meet the requirements of NCAMP Authorized Engineering Representative (AER) Qualification Plan (NCAMP Document No. NQP 200) and be approved by the NCAMP Manufacturers Advisory Board members participating in a given program. An AER may be an independent/self-employed engineer or may be employed directly by the company that is performing the tasks for NCAMP. In the latter case, the AER must not work for the same engineering department and must be able to provide impartial engineering approval or recommendation for approval.

For document review tasks, the AER is usually paid by the entity that is funding the qualification program. For test witnessing task, the AER is usually paid by the testing lab or the entity that is funding the qualification program.

- independent review*/recommend document acceptance
- witness testing
- accept test data

Proposed: EASA CVE (with appropriate composites experience identified in capabilities)

- direct AER function

or

- finding appropriate AER

* supported by/or initially EASA/NAA (review, but not recommend)

Composite Shared Databases:

NCAMP SOPs and European Functionaries:

Authorised Inspection Representative (AIR):

2.5.1 Authorized Inspection Representative (NCAMP AIR)

An NCAMP AIR is an individual qualified to conduct independent/un-bias inspection verifications. This individual's regular job function includes inspection verification of test panels and specimens. Companies and testing laboratories that participate in NCAMP activities typically have internal quality procedures and conduct internal inspection on test articles. In such cases, the NCAMP AIR may elect to conduct inspection verification on representative samples of test articles to ensure that the internal quality procedures and inspections are adequate. The NCAMP AIR may conduct more rigorous inspection verification frequency, at the sole discretion of the NCAMP AIR, if the internal quality procedures and inspections are deemed inadequate. Individuals desiring to hold this position must meet the requirements of NCAMP Authorized Inspection Representative (AIR) Qualification Plan (NCAMP Document No. NQP 100) and be approved by the NCAMP Manufacturers Advisory Board members participating in a given program. An AIR may be an independent/self-employed inspector or may be employed directly by the company that is performing the tasks for NCAMP. In the latter case, the AIR must not work for the same inspection/quality department and must be able to provide impartial inspection verification.

- independent test article inspection verification
- supports AER*

Proposed: EASA CVE (with appropriate composites experience identified in capabilities)

- direct AIR function

or

- finding appropriate AIR

* CVE not to be both AIR and AER on same project!

EASA
European Aviation Safety Agency

End slide

Your safety is our mission.

An agency of the European Union