Generic Material Issues

'Engineering Properties', design, and 'end to end' supply chain management

- 'Lessons Learned'

- REACH, Critical Part Material Supply Chains, Environmentally Assisted Cracking (EAC)

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Rotorcraft Structures Workshop

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Material and Process… importance in the Regulations

- EC No 216/2008 annex 1.a.**Structures and materials**: the **integrity of the structure must be ensured throughout, and sufficiently beyond, the operational envelope for the aircraft,** including its **propulsion system**, and maintained for the **operational life** of the aircraft.

- **21A.31 Type Design … consists of:**
  - 2. Information on **materials and processes … methods of manufacture and assembly…**

BASIC REGULATION
(EU) 2018/1139

IMPLEMENTING RULES
Initial and Continued Airworthiness

- **21A.147(a) Changes to approved production organisation**

PART 21, M, 145, 66, 147
Acceptable Means of Compliance,
Guidance Materials,
Certification Specifications (CSs)

e.g. AMC 20-29 Composite Aircraft Structure

- e.g. CS25 **Certification Specifications:** ‘Not Material and/or Process specific’

CS 25.603: Materials
CS 25.613: Mechanical Strength Properties and Design Values

EU Parliament
EU Council

EU Commission

EASA

Binding

Non-Binding

Note: CSs binding once in ‘Type Design’

EASA

Engineering properties

AM ‘Engineering Properties’ are defined:

- by the ‘material/process/fabrication method’
- during consolidation of the complex part or repair

PROCESS!, PROCESS!, PROCESS!

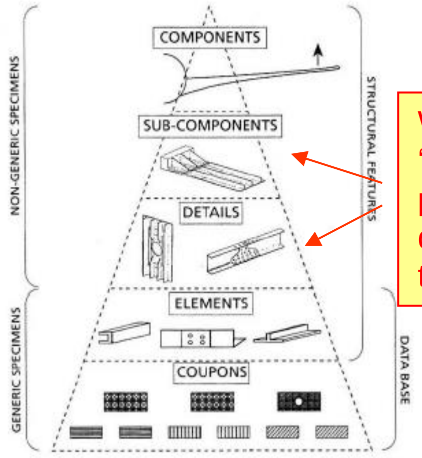


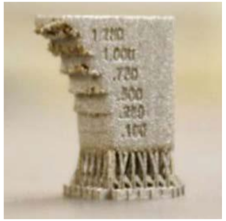
Figure 1 - Schematic diagram of building block tests for a fixed wing.

Where are the ‘engineering properties’ developed in the pyramid?

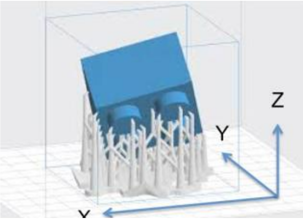
challenges:

- complex parts
- sensitive processes
- competing anomalies, flaws, defects, damage and failure modes, <u>some difficult to detect</u>

e.g. additive manufacturing, composites, bonded joints, some advanced alloys



e.g. no access to free edges – fatigue issue?



e.g. support structure on the build platform

EASA

Generic Material Issues

REACH

(Registration, Evaluation, Authorisation, and Restriction of Chemicals)

see support slides

REACH

ECHA*/REACH…

ECHA has its own set of objectives, e.g. addressing health and safety, environmental issues etc

…encourage the progressive substitution of SVHC**s with safer alternatives***

… potential significant impact upon aviation industry

A growing and potentially very significant task!

… EASA working with ECHA since 2012

NOTE NEW EASA REACH Link: ttps://www.easa.europa.eu/en/domains/environment/reach-and-aviation

* European Chemical Agency
https://echa.europa.eu/regulations/reach/understanding-reach
** SVHC Substance of Very High Concern
*** whilst allowing use to continue where it is safe and/or of high value…permit use to continue where it is justified, based on authorisation applications which are evaluated and approved on a case-by-case basis.

REACH

REACH Authorisation - a "mission-critical" process for the aerospace and defence industry … due to the following characteristics:

- The level of qualification and regulatory controls associated with introduction of alternative chemicals or other design change

- The industry's dependence on certain substances of very high concern to meet key functional requirements, in particular high standards of safety over long product lives

- The complexity of the supply chain (including but not limited to chemical manufacturers, importers, distributors, formulators, component manufacturers, OEMs, Airline operators, and aftermarket repair and overhaul activities).

- The relatively small volumes of chemicals used by the industry

- How do industry and regulators know that such material is in the supply chain and that a change has occurred? … a particular challenge for small organisations/segmented supply chains (non - TCH DOA supporting MROs, STCHs etc)?

- Once/if identified, established regulation and guideline processes exist to driving need to assess change, e.g.

- PART21, AMC 20-29 appendix 3 for composites, CMH-17
- 'Performance Based Regulation'
- 'Level of Involvement' (certification effort proportionate to criticality, novelty, complexity etc)

- Are we confident...

- specs and/or supplier-customer agreements adequately communicate all necessary information to all who need to know in complex supply chains?
- do all DOAs understand the potential impact, and what actions are necessary, if informed?

REACH

REACH Authorisation – progress/application examples to EASA

*update (5th June 2024) …a second call for evidence necessary… a task requiring considerable work!

- **metallic** , developing activity focused on **Cr (VI)*** (also includes surface prep/coatings for some non-metallics), e.g. corrosion and wear resistance

Challenges – current issues: finding replacements which work (cad plating v ceramic anti-corrosion coatings?, and defining the extent of necessary resubstantion test and analysis work, e.g. scaling coupon data to complex parts may not always work, e.g. some Sulphuric Acid Anodising replacements (e.g. undercarriage)

- **non-metallics** (e.g. **PFAS (per- and polyfluoroalkyl substances**)** – significant to many adhesives, sealants, ancillary materials - full scope/timeline TBD)):

Challenges – pending issues:

**5642 comments being processed from 2023 proposal!
- further processing likely to last until 2026… a task requiring considerable work!

- thorough 'end to end' supply chain management necessary throughout raw material management to part production processes in order to establish, and maintain, properties, particularly for 'critical parts'

Generic Material Issues

- Critical Part Material Supply Chains

  ‘Lessons Learned’ e.g. Titanium

see support slides

Generic Material Issues

Example: Process sensitive materials – 'Lessons Learned'…previously by propulsion

Sioux City DC10 accident July 1989 (296 occupants, 111 fatalities)

- Ti fatigue failure (stage 1 fan disk) - uncontained No.2 engine debris – severed flight control systems
- alloy can exhibit 3 major melt related anomolies* (defects difficult to detect/missed)
  - Type I hard alpha inclusions
  - high density inclusions
  - segregation (Type II hard alpha segregates or beta flecks

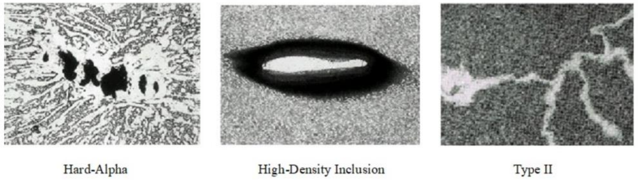


Figure 1: Optical micrographs of hard-alpha, high-density and Type II inclusions

Note: at this time, other separate (unrelated) cases of contaminated Ti 'sponge' evident in the supply chain, sponge also being raw material from which Ti is produced and a known source of hard alpha, if contaminated

PROCESS!, PROCESS!, PROCESS!

*https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR-90-06.pdf

Generic Material Issues

Example: Process sensitive materials – ‘Lessons Learned’

Outcome:

- improved ‘critical’ process for ‘critical parts’ – raw materials through to parts

- improved melt technology and quality improvements *,
    - **replace ‘double melt’ with ‘triple melt’** (e.g. 3x VAR (Vacuum Arc Remelt))
    - intoduce Hearth Melt VAR (HMVAR)
- more rigorous supply chain management
- improved technical standard evolution, e.g.
    - AC 33.15-1 ‘Manufacturing Process of Premium Quality Titanium Alloy Rotating Engine Components’
    - AMS2380 ‘Approval and Control of Premium-Quality Titanium Alloys’

+ Engine TCH additional and/or TCH only ‘in-house’ standards involving direct engagement/oversight of melt facilities supplying materials for critical parts

*Jet Engine Titanium Quality Committee (JETQC) and Rotor Integrity Steering Committee (RISC)

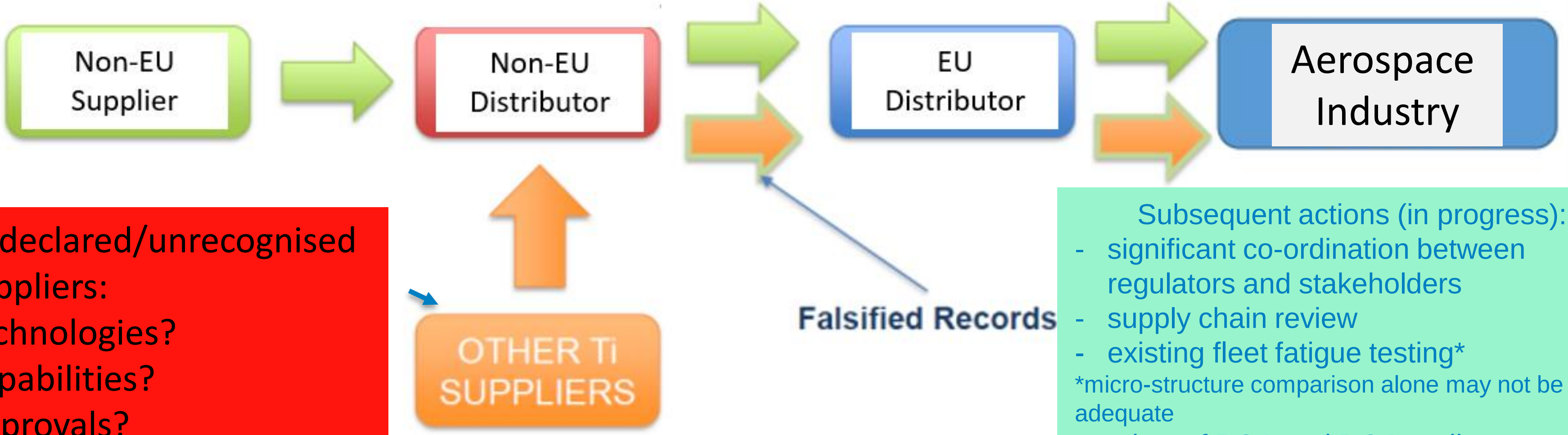
‘Lessons Learned’:

- importance of strict process control to define and maintain design properties

Generic Material Issues

Recent Example: Process sensitive materials

- EU distributor detected heat number mis-match in supply chain for materials used in single critical load path dynamic parts (importantly communicated with ENAC, shared with EASA)
- subsequent investigation indicated 5+ unrecognised melt sources added to the supply chain



undeclared/unrecognised suppliers:
Technologies?
Capabilities?
Approvals?

Subsequent actions (in progress):
- significant co-ordination between regulators and stakeholders
- supply chain review
- existing fleet fatigue testing*

*micro-structure comparison alone may not be adequate

- review of POA and DOA audit processes to be considered

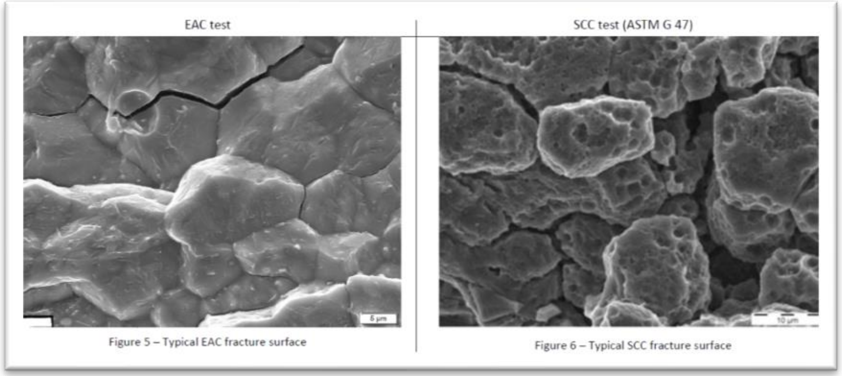
Generic Material Issues

- Environmentally Assisted Cracking (EAC)

see support slides

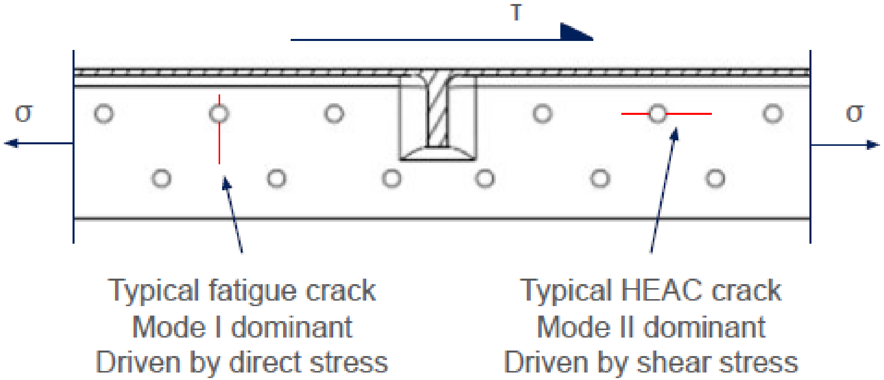
EAC History

Note: (H)EAC* cracks typically not so obvious as 'typical' fatigue cracks – need for NDI in place of visual for some ADs – see later



(H)EAC

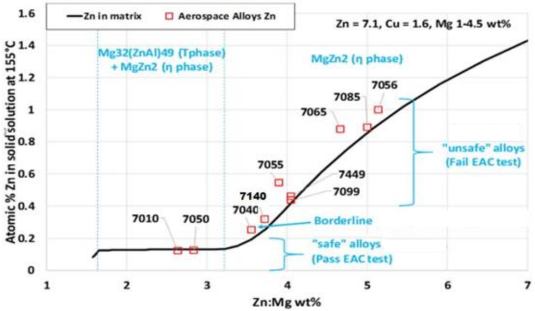
SCC – pitting + corrosion products?



These cracks typically start from holes or other areas of stress concentration and usually propagate in a plane perpendicular to the short transverse (ST) direction. This phenomenon has been linked to the chemical composition of the alloy, notably a high zinc/magnesium ratio, combined with low copper content. Brittle fractures have been reproduced under laboratory environment and cracking has proven to be driven by time exposure (ageing) and is not fatigue related, although further crack propagation under operative loads cannot be excluded.

* terminology not standardised

H-EAC History



Impacted products include:
- 3 EU Large pax*
- 2 EU Rotorcraft*
- 2 Validation Products
- Military Products

*ADs issued

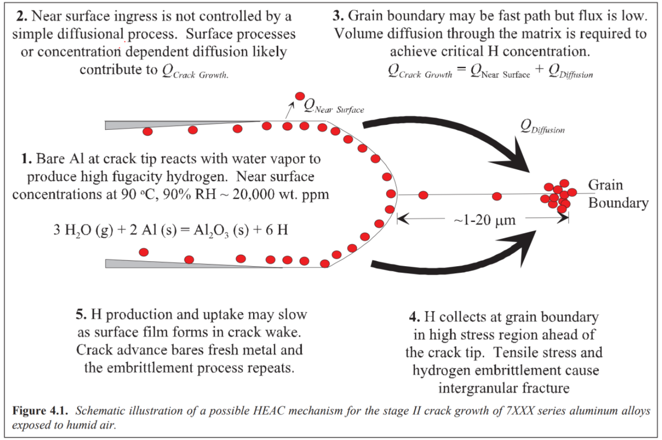
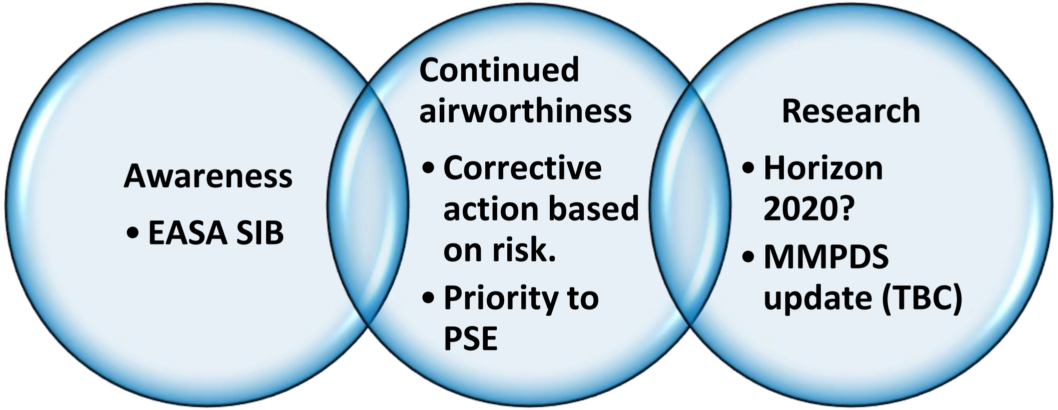


Figure 4.1. *Schematic illustration of a possible HEAC mechanism for the stage II crack growth of 7XXX series aluminum alloys exposed to humid air.*

Further observations:
- cracking perpendicular Short Transverse (ST)direction combined with interference fit
- does not follow 'conventional' F&DT crack growth laws
- multiple cracks, but parts randomly affected: different parts installed on the same aircraft can be severely or barely affected!
- 'protective' layers, e.g. paint, may not protect!
- understanding of mechanism not standardized, e.g. link between environment and hydrogen embrittlement?

EAC SIB

02440087.pdf



Safety Information Bulletin 2018-04

- **6 Aluminium Alloys are listed in EASA SIB :** 7037, 7040*, 7055, 7085, 7099, and 7449
- **EAC phenomenon can occur only when the three following conditions are present**: (1) susceptible material alloy, (2) sustained stress in the ST direction and (3) ageing in a typical environment
- **EASA recommends all affected organisations to evaluate the extent of the issue**, particularly to:
  - Identify components made of EAC sensitive aluminium alloys.
  - Evaluate the sensitivity to and criticality of EAC in the component.
  - Report these evaluation results to EASA.

Note: **SIB Revision 2018 04R2 March 2021**:
- added 7140 (T7651 temper)
- provides a ‘generic’ test method intended to be used to support identification of material susceptibility to this form of EAC. However, this needs further revision…

H-EAC Future Developments*

- **alloy selection** could be better “controlled” (avoid EAC materials – high Zn/Mg ratio, low Cu etc)

- better standardise terminology and understanding of mechanism

- need to better standardise/improve test methods, e.g. to identify key parameter values: loads, environment, temperature…

- continue to inform industry of progress: identified product CAW actions in progress, revise SIB

- improve understanding of crack growth - HEAC cracks are Mode II vs Mode I for conventional F&DT… longer term solution? ….complex approaches like J-integral to capture the stability of the crack tip?

* **AFRL-FAA Technical Interchange Meeting (TIM) on Environmentally Assisted Cracking (EAC) / Stress Corrosion Cracking (SCC) of High-Strength 7000 Series Aluminum Alloys, 5-6 November 2024** (proceedings to be published)… to be continued

Generic Material Issues

Conclusion/Reminder: **REACH/Ti – Supply Chain Management/EAC:**

- identifying Key Process Parameters (KPPs) and understanding the sensitivities of 'engineering properties' to KPPs is essential to safety (considering design cert, production, and in-service)

- 'change' already addressed in PART 21

- identifying changes may be a challenge

- understanding importance of changes to 'engineering properties' and safety (design cert, production, and in-service) and defining a proportionate 'equivalence' strategies may involve significant work

- thorough 'end to end' supply chain management necessary throughout raw material management to part production processes in order to establish, and maintain, properties, particularly for 'critical parts' Reminder: A POA may not be a melt specialist!

- technical engagement beyond high level procedures is important, e.g. AS 9100 **+ technical specs (Standard Development Organisation (SDO) and/or in-house TCH specs) should be clearly demonstrated… particularly for dynamic single load path critical parts**

EASA

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DO NOT HIDE IN HIGH LEVEL PROCEDURAL SILOs!

EASA

European Union Aviation Safety Agency

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Your safety is our mission.

easa.europa.eu/connect

Thank you for your attention!

Support Slides

Material and Process… importance in the Regulations

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- 21A.31 Type **design** … consists of:
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AMC 20-29 Composite Aircraft Structure

Basic Regulation

(EU) 2018/1139

Implementing rules

Initial Airworthiness

For the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations.

Implementing rules

Continued Airworthiness

On the continuing airworthiness of aircraft … parts and … approval of … involved in

- **21A.147(a) Changes to approved production** organisation. GM 21.A.147(a) – Significant Changes 1… significant changes to production methods

Part 21

- Acceptable means of compliance (AMC)
- Guidance material (GM)

Certification specifications

- Airworthiness codes

Acceptable means of compliance (AMC) Guidance Material (GM)

- Part M – Continuing Airworthiness
- Part-145 – Maintenance Organisations Approvals
- Part-66 – Certifying staff
- Part-147 – Training organisations requirements

- e.g. CS25 **Certification Specifications**: Limited 'Material and Process'

CS 25.603: Materials… 'suitability and durability … based upon experience/test… conform to specifications… consider environment

CS 25.613: Mechanical Strength Properties and Design Values Materials. (a) … design values based upon a statistical basis

EU Parliament
EU Council

EU Commission

EASA

Binding

Non-Binding

Note: CS binding once in Type Design

EASA

Material and Process… importance in the Regulations

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BASIC REGULATION
(EU) 2018/1139

IMPLEMENTING RULES
Initial and Continued Airworthiness

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PART 21, M, 145, 66, 147
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Note: CSs binding once in 'Type Design'

Changes to structure etc… baseline structure, modifications, repairs etc

CS 25.605* (CS25 amdt 27): Fabrication Methods

(a) The fabrication methods used (i.e. the manufacturing and assembly methods, including consideration of the materials and material processes) must produce the strength and other properties necessary to ensure a consistently safe part. If a fabrication method includes processes that require close control to reach this objective, then those processes must be performed under representative approved fabrication **process specifications**, supported by appropriately approved **material specifications (including considering the raw/feedstock/unfinished material specifications) with appropriate controls** for the design data.

(a) Each new fabrication method must be substantiated by a test programme that is representative of the application.

*basic safe engineering 'Threat Assessment' considerations regardless of product… EASA intent to amend throughout product CSs accordingly!

Changes to structure etc… baseline structure, modifications, repairs etc

CS 25.571*: Damage tolerance & fatigue evaluation of structure

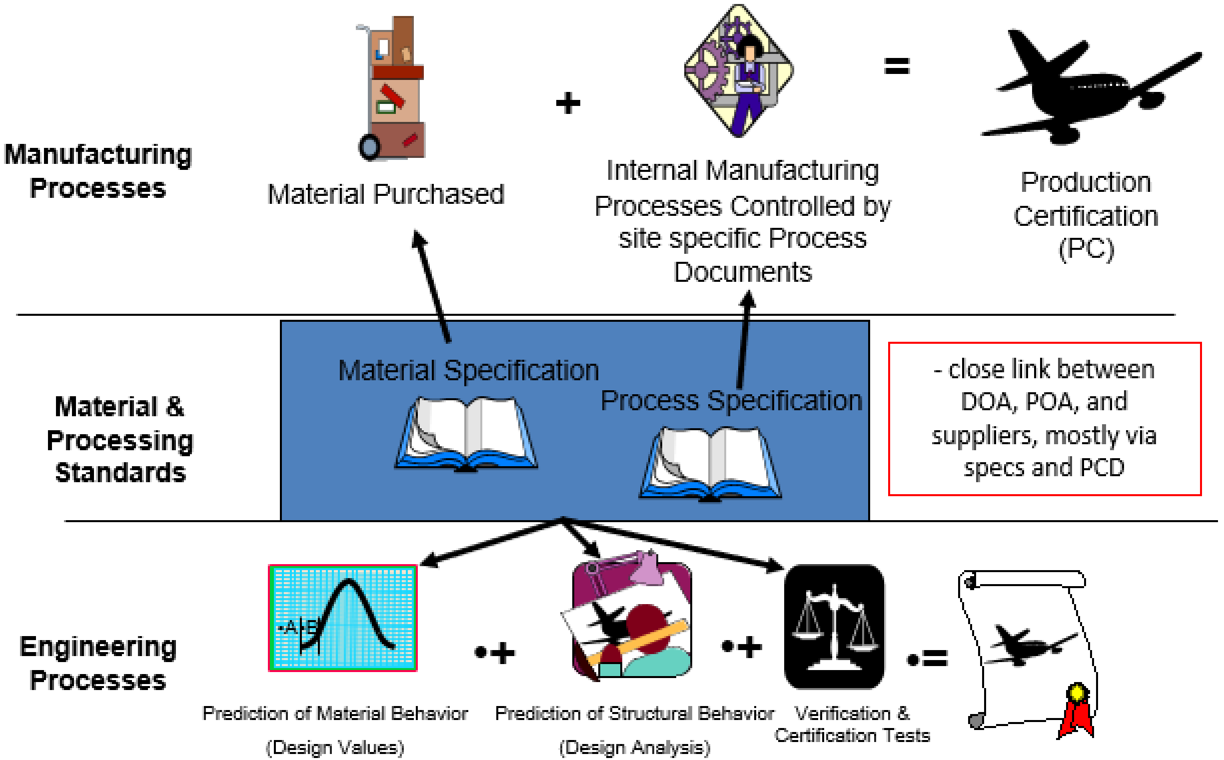
(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to **fatigue, manufacturing defects, environmental deterioration, or accidental damage** will be avoided throughout the operational life of the aeroplane

(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'

*basic safe engineering 'Threat Assessment' considerations regardless of product!

Manage via Process Control Document (PCD)… or similar

Note: Integrated process relying upon 'end to end' knowledge



REACH

REACH - REMINDER

Although an ECHA driven process, potential to impact aviation materials and ‘engineering properties’ needs to be addressed...

…aviation industry operates in environments which are highly challenging, due to the varied conditions, …such as extremes of temperature and humidity, and the stringent aviation safety requirements which must be met.

…will need to continue to use high-performance preparations, mixtures and formulations, some of which contain substances which have been placed in Annex XIV of the REACH Regulation 1907/2006 – implemented by the European Chemicals Agency (ECHA) – or which could be placed there in future.

REACH

The critical reliance of the aviation industry on Annex XIV substances, and the difficulty in finding and adopting suitable alternatives, mean there has been concern in the EASA and the aviation industry generally to ensure that the REACH authorisation requirements do not lead to unnecessary disruption to normal operations in aviation.

…in October 2012, EASA approached ECHA to explore how the two Agencies could cooperate, ref.2014 ECHA – EASA Report

http://www.easa.europa.eu/system/files/dfu/20140415%20Published%20report.pdf

EASA and the European Chemicals Agency (ECHA) have established a partnership to ensure aviation safety is ensured while implementing the REACH regulation in line with Article 87.2 of the EASA Basic Regulation. For more information see "An elaboration of key aspects of the authorisation process in the context of aviation industry".

REACH

ECHA/REACH… Engineering Property/Regulatory Impact…

…performance specifications drive the choice of substances to be used either directly in the aircraft or during the manufacturing and maintenance activities…e.g.

Resistance to deterioration (e.g. corrosion) Environmental damage (corrosion for metal, delamination for composites) and accidental damage during operation or maintenance.

Corrosive fluids - Hydraulic fluids; Blue water systems (toilet systems and areas); leakage of corrosive fluids/substances from cargo.

Microbiological growth in aircraft fuel tanks due to moisture/contamination in fuel cause severe corrosion. Such corrosion debris has the potential to dislodge from the fuel tanks, migrate through the fuel system, and lead to an in-flight engine shutdown.

Resistance to fire – Flammability Requirements Fire-proof and fire-resistance. Aircraft elements are expected to withstand fire for a specified time without producing toxic fumes; this leads to using products like flame retardants, insulation blankets, heat protection elements in hot areas (e.g. around engines).

REACH

PFAS – minor update

https://echa.europa.eu/de/hot-topics/perfluoroalkyl-chemicals-pfas

Latest updates

Universal PFAS restriction proposal:

- Committees for Risk Assessment and for Socio-Economic Analysis meet in June - stakeholder registration open until 9 May 2024
- Dossier Submitter's ongoing role in the PFAS restriction proposal - news from German BAuA, 15 April 2024
- Next steps for PFAS restriction proposal, 13 March 2024
- Highlights from November RAC and SEAC meetings, 7 Dec 2023
- Enforcement Forum's advice on enforceability of the proposed PFAS restriction, 8 Nov 2023
- All comments submitted to the PFAS restriction proposal now online, 2 Nov 2023

Restriction proposal on PFAS in firefighting foams:

- ECHA's committees: EU-wide PFAS ban in firefighting foams warranted, 22 June 2023

Other:

- Member States vote to restrict PFHxA in the EU, 29 February 2024
- Perfluoroheptanoic acid (PFHpA) and its salts added to Candidate List of substances of very high concern, 17 January 2023

5642 comments being processed from 2023!
- further processing likely to last until 2026

REACH

PFAS – minor update

https://echa.europa.eu/de/hot-topics/perfluoroalkyl-chemicals-pfas

Figure 2: Indicative time table of the REACH restriction process for PFAS

For further information on REACH and aviation see easa.europa.eu/reach

REACH

REACH Authorisation – potential application examples to EASA

- intent/expectation to need to address non-metallics (full scope/timeline TBD) e.g. industry/regulator dialogue (ASD – STAN):

- current developing activities include PFAS (per- and polyfluoroalkyl substances)

- PFAS composite interests include:
    - release films (ETFE, PTFE, and FEP-based mold release films)

NOTE: Developing impact of REACH PFAS issues on Hydrogen Technology

REACH

Chromates – minor update (longer term milestones TBD)

https://www.complianceandrisks.com/blog/eu-reach-hexavalent-chromium-crvi-changes-to-regulatory-approach/

- update (5th June 2024) on the intention to prepare a restriction proposal on certain Cr(VI) substances under REACH, and launch of a second call for evidence:

  - the scope and timeline to prepare the Annex XV restriction dossier have been extended
    - addition of barium chromates (chromium ion carrier.. link to Cr(VI) issue)
    - second call for evidence (two aspects) started on 5 June 2024 and will last until 15 August 2024
      - Various uses of Cr(VI) substances
      - Alternatives to Cr(VI) substances

REACH

REACH Authorisation – application **examples** to EASA

- initial intent and change process evident to EASA, 2013 onwards, significant increasing activity*

- typically **metallic** (e.g. undercarriage), developing activity focused on **Cr (VI) includes surface prep/coatings for some non-metallics**, e.g.
  - replace cadmium plating with metal ceramic anti-corrosion coating
  - replace cadmium plating and metal ceramic anti-corrosion coating with Zn-Ni
  - replace Sulphuric Acid Anodising (SAA) spec to remove nonylphenol (resulted in challenges regarding coupon data not representing complex part data, resulting in replacement)

*update (5th June 2024) …a second call for evidence necessary… a task requiring considerable work!

*large TCHs seem to be engaged. Others?

REACH

*5642 comments being processed from 2023 proposal!
- further processing likely to last until 2026… a task requiring considerable work!

REACH Authorisation – potential application **examples** to EASA

- intent/expectation to need to address **non-metallics** (full scope/timeline TBD), e.g. quote previous industry/regulator dialogue (2018):

PFAS (per- and polyfluoroalkyl substances)

Chromium trioxide is one example. We anticipate similar concerns for other substances which are widely used in aerospace components and processes, and which are expected to be banned in the near future, e.g.:

- Bisphenol A, Siloxanes (D4, D5, D6) and Terphenyls, which are all the backbones of adhesives and sealants used broadly on aerospace hardware (epoxies, silicones and sealants)
- Elemental lead, which is critical for use in solder and journal bearings, as examples
- UV-328, which is used in many aerospace coatings with no alternative currently available

- developing issue of potential significance to composite industry, scope and timescales TBD*.

Generic Material Issues

Conclusion/Reminder: **REACH:**

- ‘change’ already addressed in PART 21

- multiple potentially REACH impacted materials in supply chain. Identifying these will be a challenge, particularly for complex segmented supply chains, e.g. DOA supporting MROs, STCHs etc.

- understanding importance of changes to ‘engineering properties’ and safety (design cert, production, and in-service) and defining a proportionate ‘equivalence’ strategies may involve significant work

- thorough ‘end to end’ supply chain management necessary throughout raw material management to part production processes in order to establish, and maintain, properties, particularly for ‘critical parts’

- the magnitude of the challenge (existing and new products!) is becoming evident in industry regulator dialogue.

To Be Continued…

NEW EASA REACH Link: ttps://www.easa.europa.eu/en/domains/environment/reach-and-aviation

EASA

PAY ATTENTION TO SUPPLY CHAIN INTERFACES and CHANGES!
DO NOT HIDE IN HIGH LEVEL PROCEDURAL SILOs!

Generic Material Issues

Example: Process sensitive materials – ‘Lessons Learned’

Sioux City DC10 crash July 1989 (296 occupants, 111 fatalities)

- uncontained No.2 engine debris – severed flight control systems

  (continued flight to crashland at Sioux City, possible partly by differential power management of remaining engines)

- fatigue failed part manufactured from **double melt Ti** ingot

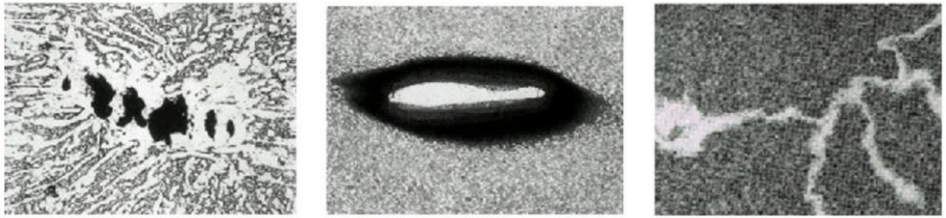
*https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR-90-06.pdf

Generic Material Issues

Example: Process sensitive materials – ‘Lessons Learned’

- alloy can exhibit 3 major melt related anomolies* (defects difficult to detect/missed)
    - Type I hard alpha inclusions
    - high density inclusions
    - segregation (Type II hard alpha segregates or beta flecks)

PROCESS!, PROCESS!, PROCESS!



Hard-Alpha   High-Density Inclusion   Type II

Figure 1: Optical micrographs of hard-alpha, high-density and Type II inclusions

Note: at this time, other separate (unrelated) cases of contaminated Ti ‘sponge’ evident in the supply chain, sponge also being raw material from which Ti is produced and a known source of hard alpha, if contaminated

*Aerospace Titanium Alloy Melt Process Quality Improvements | MATEC Web of Conferences

Generic Material Issues

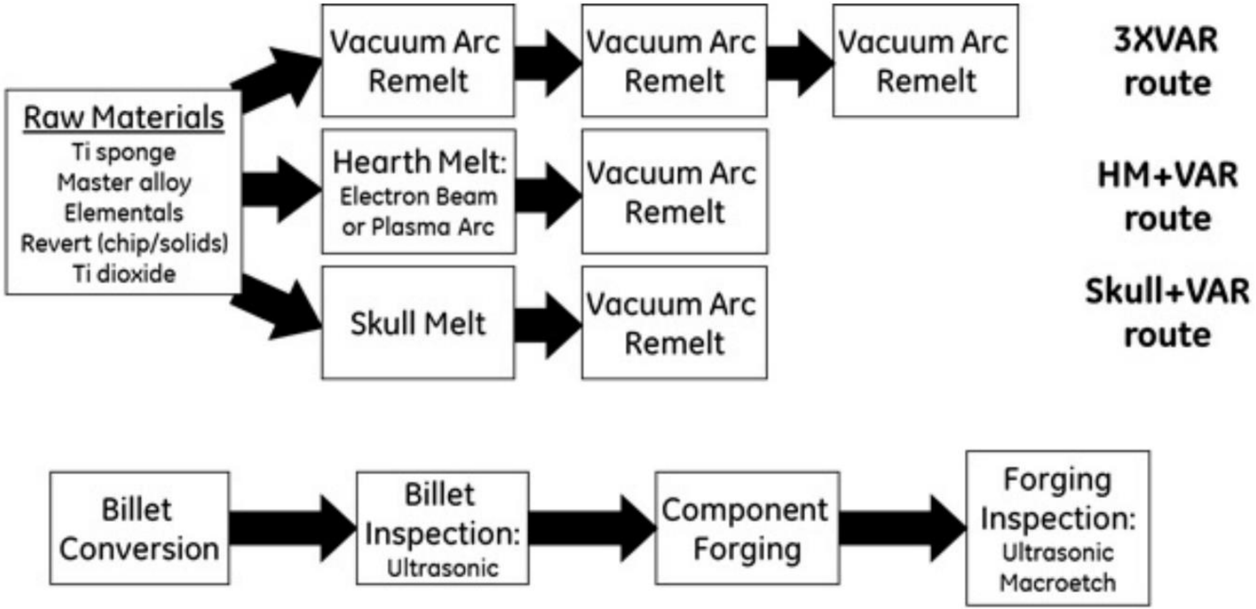


Figure 2: PQ Ti process map illustrating the three current Ti alloy melt process

Generic Material Issues

Broader conclusions:
- significant 'lessons learned' by propulsion community potentially useful to other sensitive processes and/or products
- significant effort to improved process sensitive material management and technology from melt

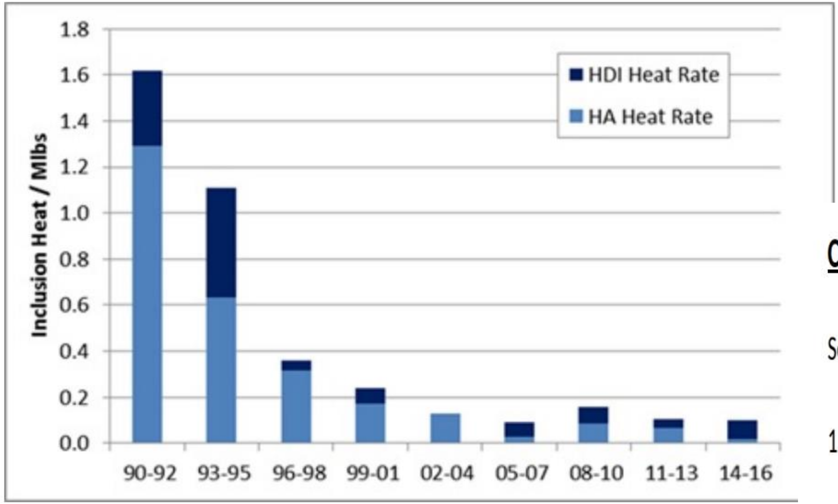


Figure 3: Hard-alpha and high-density inclusion rates since 1990

Conclusions

Several conclusions can be drawn from this work:

1. JETQC membership has expanded and is expected to continue to expand.

2. The entire PQ Ti industry has focused on the threat of melt-related inclusions to improve air travel safety and through co-operative efforts with the FAA, the suppliers and the OEMs has resulted in a significant reduction in risk.

3. HMVAR melt process has been demonstrated to be extremely robust and has consistently delivered the highest level of PQ Ti quality to the industry. The statistics support that the final VAR melt step has been well-controlled.

Generic Material Issues

Recent Example: Process sensitive materials

- noting sensitivity of Ti to difficult to detect defects, significant impact upon customers, and potential safety concern needing investigation:

- event followed by significant co-ordination between regulators and stakeholders to address existing and future fleets (in progress)
    - supply chain review
    - existing fleet material review
    - additional testing necessary

Note: microstructure investigation, alone, may not be adequate to detect any issue, fatigue testing also necessary

Generic Material Issues

Conclusion/Reminder: Critical Part Materials Supply Chains

- Basic Regulation, PART 21, and CS's already require necessary control of materials and processes

- some materials and processes are process 'critical', e.g. bonding, Ti production (quality does not rely upon inspection alone!). Understanding importance of process criticality to design properties is essential

- thorough 'end to end' supply chain management necessary throughout raw material management to part production processes in order to establish, and maintain, properties, particularly for 'critical parts' Reminder: A POA may not be a melt specialist!

- technical engagement beyond high level procedures is important, e.g. AS 9100 **+ technical specs (Standard Development Organisation (SDO) and/or in-house TCH specs) should be clearly demonstrated… particularly for dynamic single load path critical parts**

PAY ATTENTION TO SUPPLY CHAIN INTERFACES and CHANGES!
DO NOT HIDE IN HIGH LEVEL PROCEDURAL SILOs!

H-EAC History

Susceptible alloy

Environment*

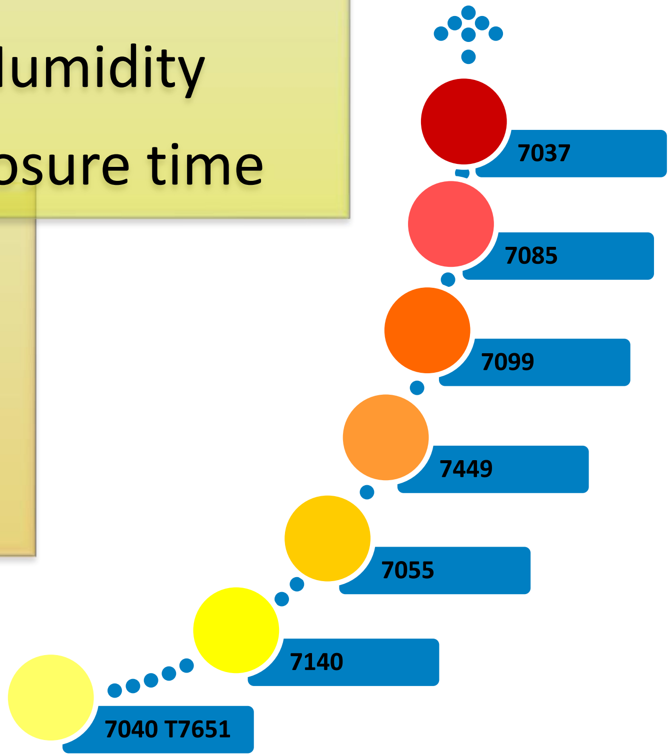
Humidity

Exposure time

EAC

3 factors

Stresses



* ‘protective’ layers, e.g. paint, may not prevent

H-EAC SIB

'Generic' test method could benefit from common protocol to optimise identifying critical temperature, environment, load etc for any particular application and alloy

Appendix 1 – EAC Generic Test Method

1. EAC generic test method and test conditions:

As suggested by public literature or published test methods:

Specimen:
- Specimen geometry: Round smooth bar → according to ASTM G49 and ASTM E8 Tension test
- Align longitudinal axis of specimen (loading direction) with the Material ST grain direction

Loading:
- Loading device: Test rig → In Style of ASTM G49
- Loading: Constant load / displacement → according to ASTM G49
- Load level: set at 85% Yield only → In the style ASTM G64

Environment:
- Level of Humidity: 85% ± 5% → Ref. 1)
- Temperature: 70°C ± 1°C → Ref. 1)

Test time:
- Test duration is recommended to be at least 100 days

Example: Adapt SCC test in accordance with ASTM G 47…. too severe?

Experimental Conditions

- **Specimen** (typically): 60mm long round bar, dia. ~3mm
- **Load:** Constant 25-75 % Rp0.2
- **Environment: 3,5% NaCl alternate immersion**
- **Temperature:** RT

H-EAC Experience/findings/comments

- The intergranular fracture generated by H-EAC does not show any microscopic corrosion indication vs **S**tress **C**orrosion **C**racking (pitting visible in the grains)

- Interference fit (stress) and environmental conditions (moisture and temperature) are contributing factors to HEAC - not easily monitored or quantified.

- Crack initiation and propagation does not follow conventional laws currently used in F&DT evaluation

- H-EAC characteristics are unpredictability & variability. Even if some of the parameters are now well identified, significant dispersion/scatter are observed in service: different parts installed on the same aircraft can be severely or barely affected.

- The “quality” or the detectability of the cracks is an additional issue to be considered for the H-EAC inspection: NDT requested

EAC findings

- Al 7085, 7075, 7449
- Perpendicular short transverse cracking combined with Interference fit
- Multiple cracks but parts randomly affected

Related ADs:

2019-0074: EC225 LP Main Rotor – Rotating Swashplate Yokes – Inspection / Rework / Service Life Limit

2019-0181R1: A350 Fuselage – Forward and Aft Cargo Door Latch Fitting External Lugs – Inspection / Modification

2021-0192: EC135B Main Rotor – Upper and Lower H legs – Service Life Limit

2022-0019: A380 Wings – Front and Rear Spars – Inspection

H-EAC Mechanism*

*understanding of mechanism not standardized, e.g. possible scenario for a link between environment and hydrogen embrittlement**
(without corrosion products)

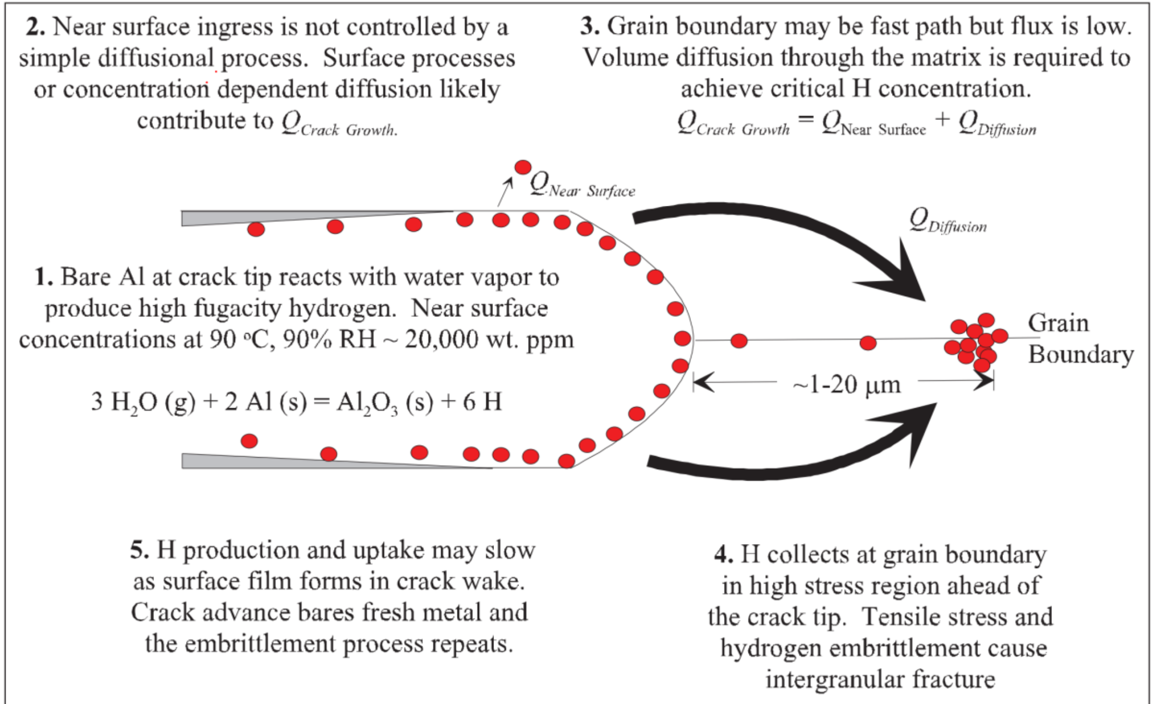


Figure 4.1. *Schematic illustration of a possible HEAC mechanism for the stage II crack growth of 7XXX series aluminum alloys exposed to humid air.*

** HYDROGEN ENVIRONMENT ASSISTED CRACKING OF AN AL-ZN-MG-(CU) ALLOY
George A. Young Jr. August 1999

Generic Material Issues

Conclusion/Reminder: **EAC:**

- advanced alloys increasingly competing with composites, some behaving more like composites, e.g. anisotropy, environmental sensitivity

- some aircraft configurations and threat scenarios may be difficult to directly certify, e.g. representative thermal and mechanical load combinations. Therefore, introduction of new materials and processes may be challenging

- the EAC issue has been recognised, e.g. EASA SIB. However, need remains to better standardise terminology, understand mechanism(s), and identify potentially vulnerable materials ,e.g. use of appropriate material selection process, testing etc

- a broader global industry – regulator dialogue has started…

To Be Continued…