GMA GROUP

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E-LASS RAMSSES

Meeting in Piteå
24.01.2019

Material‘s qualification for the aeronautical sector, An independent laboratory perspective

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One Source for Asset Protection Solutions

About GMA Werkstoffprüfung

One Source for Asset Protection Solutions

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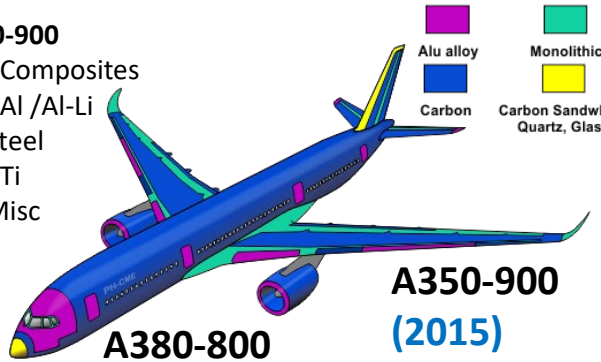
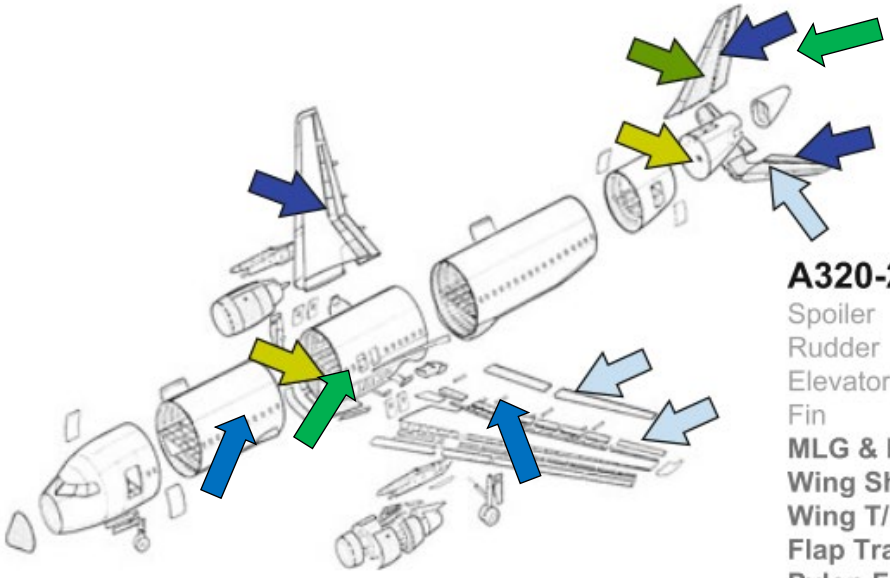
Composites in the aerospace

A350-900
52% Composites
20% Al /Al-Li
7% Steel
14% Ti
7% Misc



A350-900
(2015)
+ Wing box
+ Fuselage

A380-800
(2007)
+ Center wing box
+ Wing ribs
+ Fuselage (GLARE)
+ Rear unpress. Fuselage
+ Cross beams



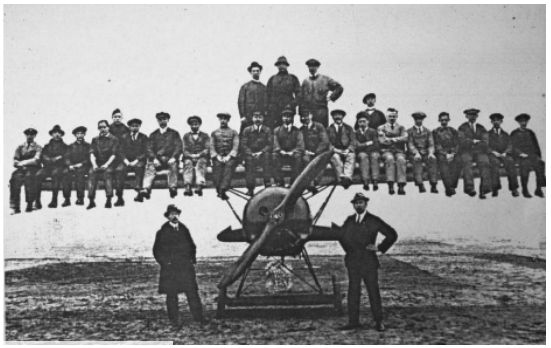
A320-200 (1987)
Spoiler
Rudder
Elevator
Fin
MLG & NLG Doors
Wing Shroud Box
Wing T/E panels
Flap Track Fairings
Pylon Fairings
Nacelle Cowlings
Floor Panels
Aileron
Flaps
Horizontal Stabilizer

A340-500/-600
(2001)
Spoiler
Rudder
Elevator
Fin
MLG & NLG Doors
Wing Shroud Box
Wing T/E panels
Flap Track Fairings
Pylon Fairings
Nacelle Cowlings
Floor Panels
Aileron
Flaps
Horizontal Stabilizer
Rear Pressure Bulkhead
Keel Beam

A310-200 (1982)
Spoiler
Rudder
Elevator

A310-300 (1985)
Spoiler
Rudder
Elevator
Fin (8.3 m)

Design Philosophies



- **Safe Life (from the 40s)**

Safety by replacement. Design is based on static properties

Issue: does not take into account damage during service

- **Fail Safe (from the 50s)**

Safety by design. Design is based on redundancy

Issue: does not take into account Multiple Site Damage and Ageing aircraft

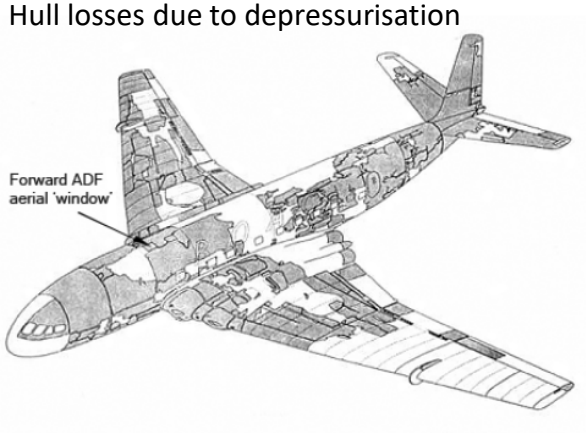
- **Damage Tolerance (from the 70s)**

Safety by inspection. Design is based on the fact that the loads can be sustained even in the case of deterioration (fatigue, corrosion, damage…) to the extent that it can be detected and restored via acceptable maintenance and inspection programs

- **Damage Tolerance Composites**

Safety by sizing. Design is based on a damage no growth approach, resulting in a max. allowable strain level of $\epsilon_{max} \approx 0.4\%$

DeHavilland DH 106 Comet (1952)
Hull losses due to depressurisation



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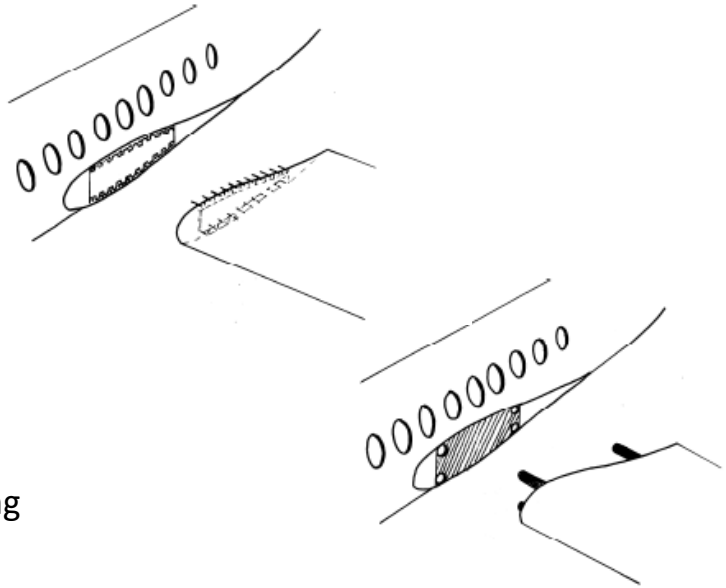
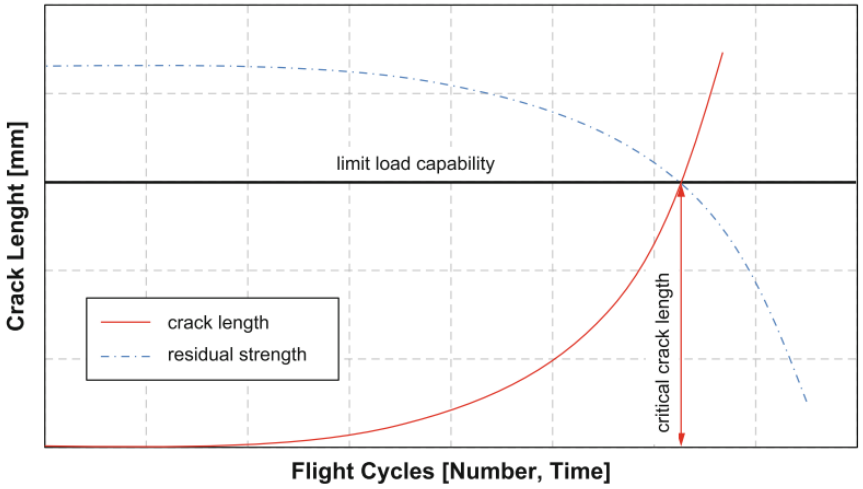
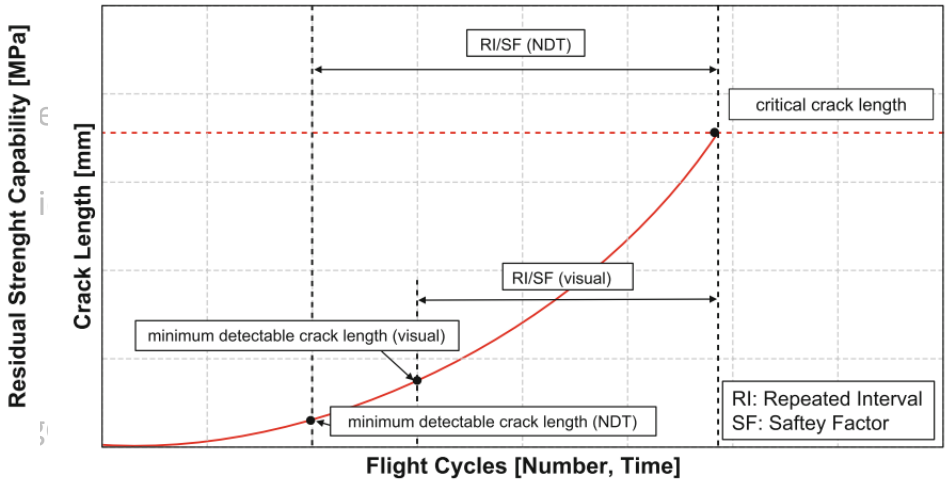


Aloha Airlines Flight 24 (1988)

Loss of part of the fuselage due to fatigue corrosion

Design Philosophies





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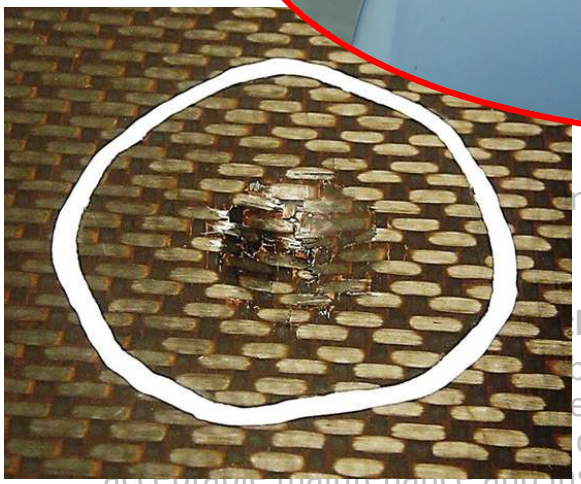

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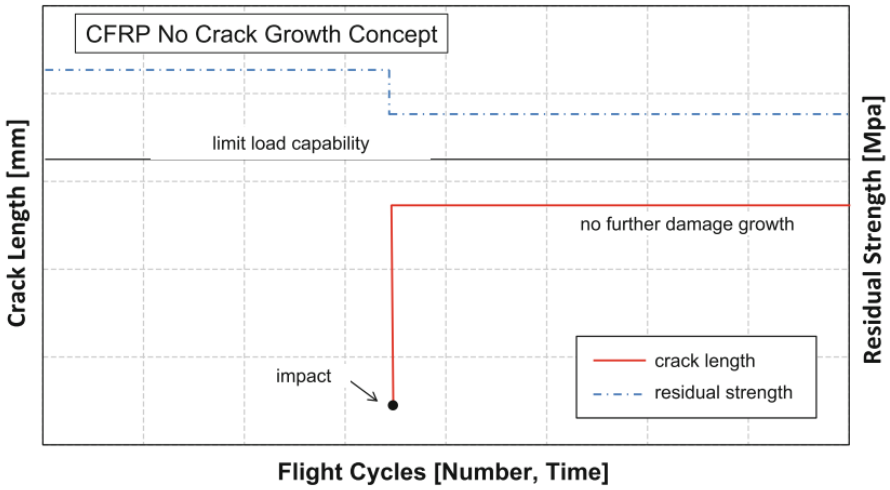

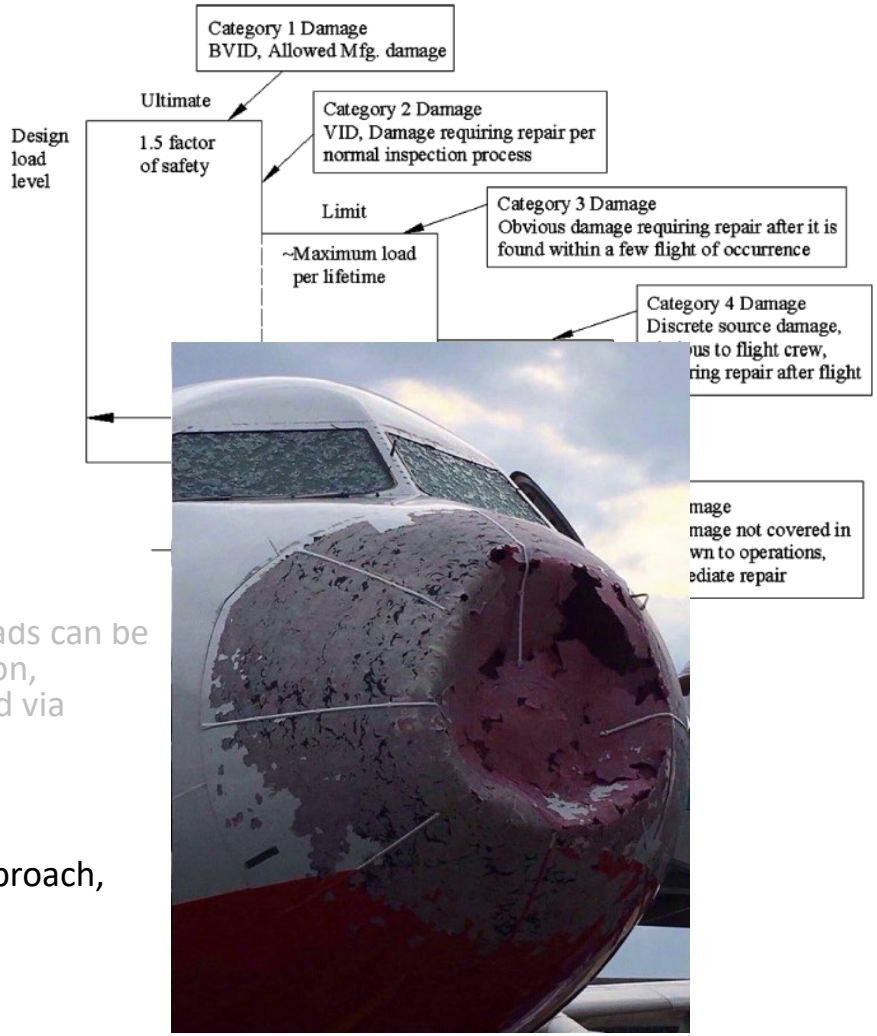

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Design and Certification process

Definition of the aircraft

(Type, Mission Profile, MTOW, DSG, operational costs)

Generation of an FE Model

Definition of the requirements

(Relevant load cases defined by JAR)

Requirement validation

(Induced design stresses ≤ Material Allowables)

Verification by experimental testing

(both on ground and flight tests)

Design and Certification process

Definition of the aircraft

(Type, Mission Profile, MTOW, DSG, operational costs)

⇩

Generation of an FE Model

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⇩⇧

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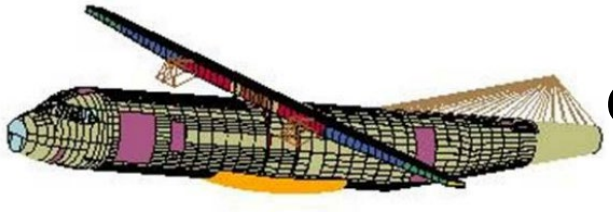
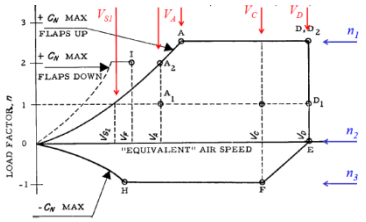


Generation of an FE Model



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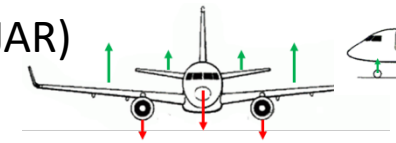

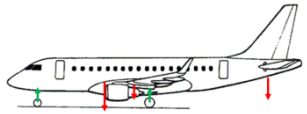

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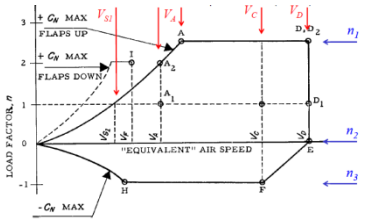

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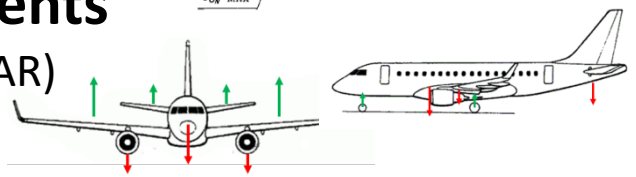

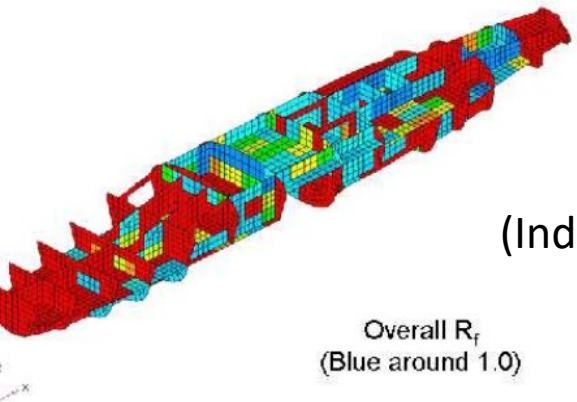

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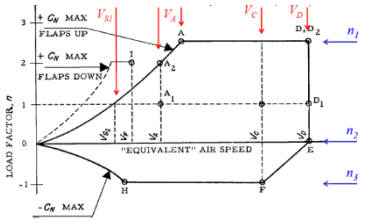

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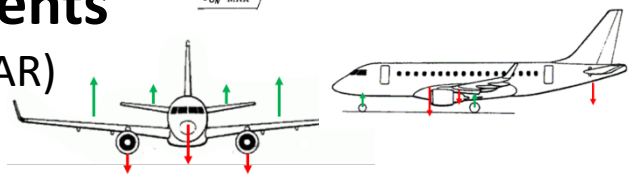

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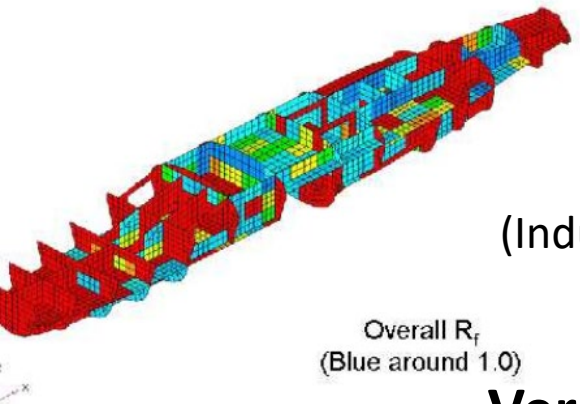

Overall R_f
(Blue around 1.0)

Requirement validation

(Induced design stresses ≤ Material Allowables)

⇩

Verification by experimental testing

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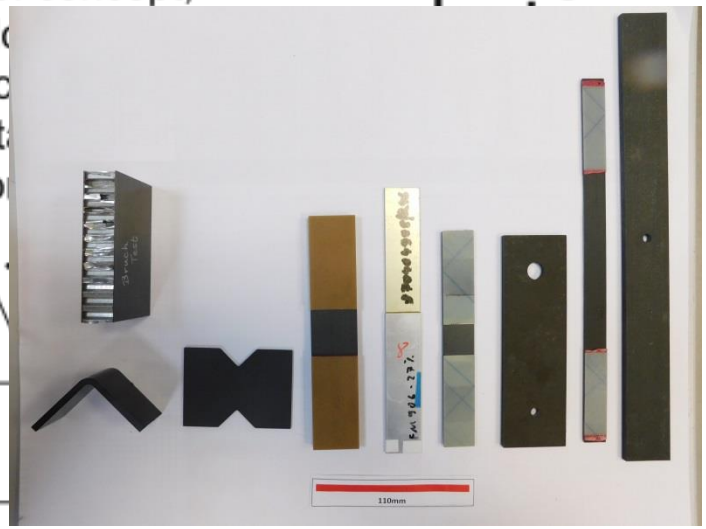
Testing Pyramid



Major or Multi-Section Tests

Major Tests

Certification o

Qualification

Components

Separate Component

Sub-Components

Proof of concept,

Details

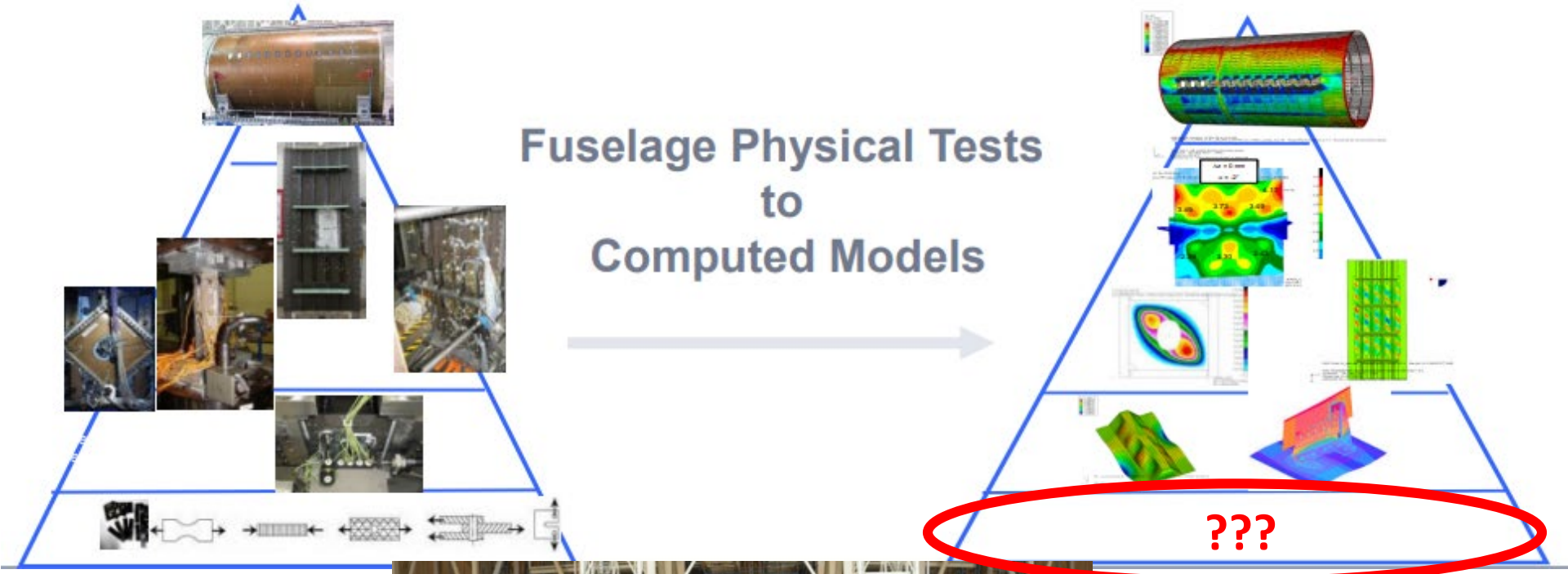
Non-Generic
(Specific)

Elements

Generic
(Non-specific)

Coupons

Testing Pyramid – virtual testing



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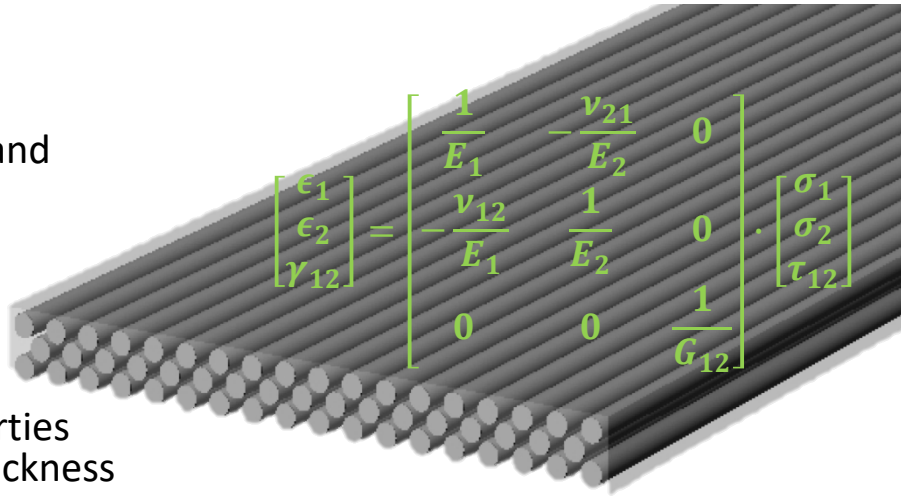
Fibre reinforced polymers – Material properties determination

- Properties are dependant on fibre orientation and fibre volume content
- Material properties are defined during the manufacturing (curing) process
- Higher material variability
- Often modelled as special orthotropic material
  → 6 independent elastic material properties
  → Reduction to 4 neglecting through thickness properties



- Layered approach
  → possibility to determine lamina or laminate properties
  → weak through thickness properties
  → prone to impact damage or delamination

- Interest into both
  – Uncured material properties: QA, manufacturing
  – Cured material properties: Design, QA

Potential tests or determining static cured material properties

- **Tensile test:**

  On 0° or 90° laminate: $E_L, \nu_{LT}, \sigma_L^{T*}, E_T, \nu_{TL}, \sigma_T^{T*}$

  or on multiaxial laminate

- **Compression test:**

  On 0° or 90° laminate: $E_L, \sigma_L^{C*}, E_T, \sigma_T^{C*}$

  or on multiaxial laminate

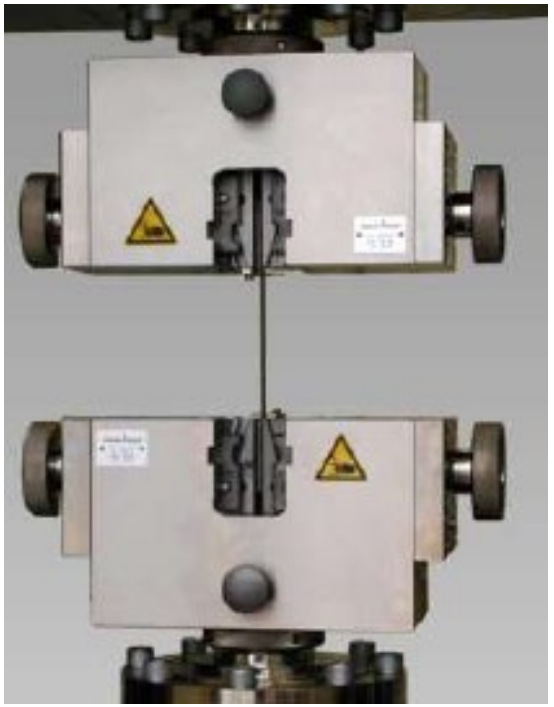
- **Shear test:**

  On ±45° or 0° laminate: G_{LT}, τ^*

- **Fracture tests:**

  On 0° laminate: $G_{Ic}, G_{IIc}, \frac{G_{Ic}}{G_{Ic}+G_{IIC}}$

ISO 527, EN2561, EN 2597, ASTM D3039, DIN 65378 ….



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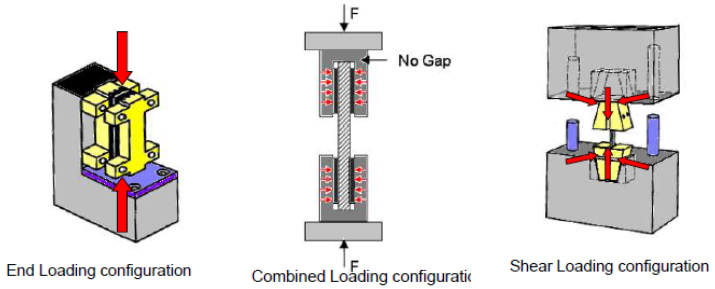
ISO 14126, ASTM D3410, EN2850, ASTM D6641 …



End Loading configuration | Combined Loading configuratio | Shear Loading configuration

Potential tests or determining static cured material properties

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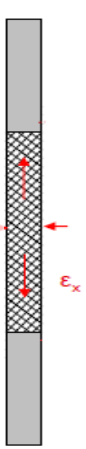

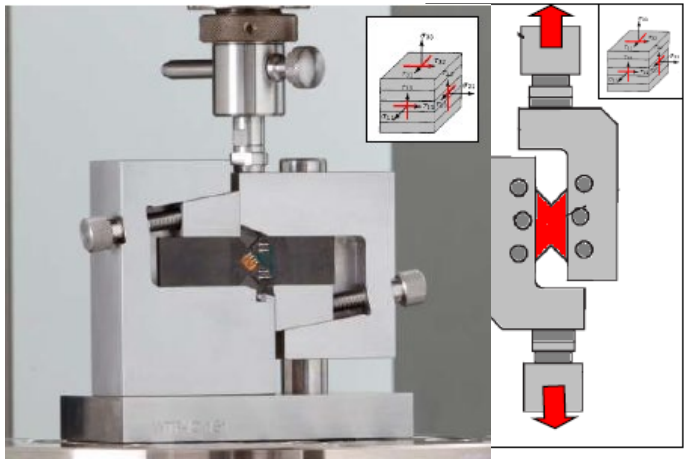

ISO 14129, ASTM D3518, ASTM D7078, DIN 65466, ASTM D5379
...

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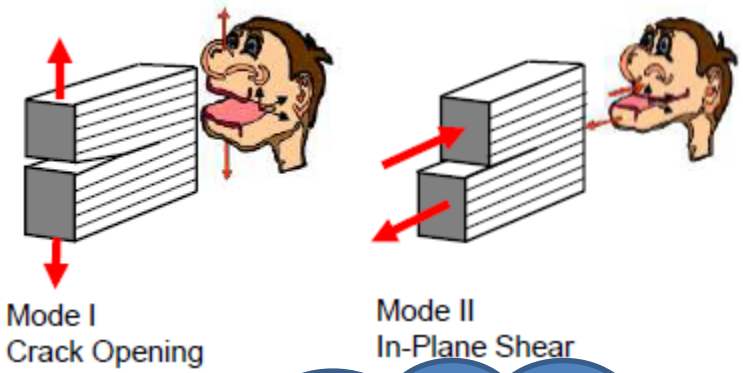
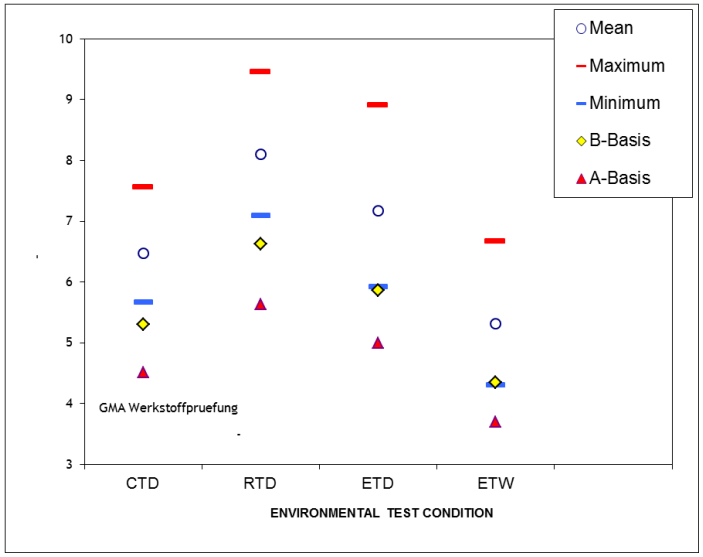


EN 6033,EN 6034, ISO 15024, ASTM D5528, ...

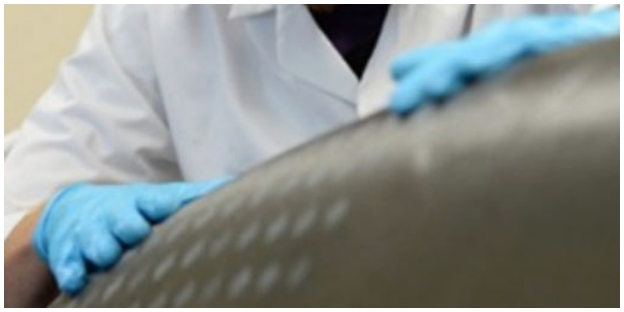
Material Qualification Process

1. Material screening
   - Validation that material has potential to be applied
2. Qualification project
   - Agreements of supply
   - Qualification of the manufacturing processes
   - Definition of a test plan (mechanical, FST,…) depending on planned application
3. Qualification test programme
   - Determination of manufacturing envelope
   - Determination of material properties and design allowables (AGATE process, A- and B-values)
4. Qualification test report
   - Documentation of the process
5. Standardization

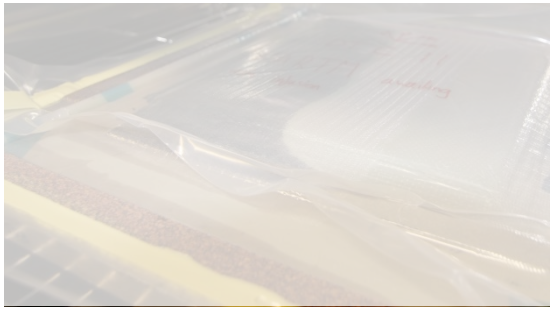


Material processing

- Main approach: Laminates using **pre-impregnated fabrics** (“pre-pregs”) manufactured using various levels of automation. Mainly thermoset resin systems, current implementation and screening of thermoplastic resins



- **Liquid resin infusion**: Dry preforms are put in contact with the resins during manufacturing. Currently used in some applications, but potentially larger usage



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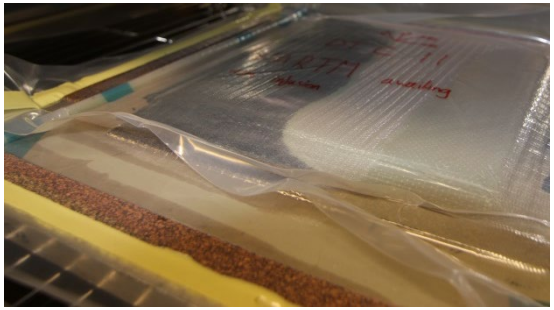

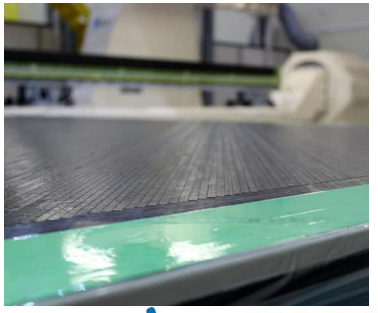

Conclusion

- Performance approach is used to qualify new materials in the aeronautical sector. Certain requirements (loads, FST,…) have to be met by the material/structure

- Definition of standard load cases that can be validated through analysis and verified through testing

Recommendations:

- Follow a Validation and Verification approach setting measurable requirements
- Explore possibility of virtual testing – perhaps using higher SF and SHM/Load monitoring
- Establish standardized test plan to determine material allowables
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Meeting in Piteå
24.01.2019

Thank you very much for your attention!

Questions?

Dr. R. Luterbacher-Mus
r.luterbacher-mus@gma-group.com

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