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A Damage Tolerance & Fatigue Evaluation Approach for Composite Rotorcraft Airframe Structures

Alexander Engleder, Davide Francescatti, Rainer Arelt
AIRBUS HELICOPTERS Deutschland GmbH
Uli Burger
Tec. University of Ingolstadt

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Introduction

Composite parts are extensively used on primary fuselage structures of many AIRBUS HELICOPTERS products like:

-H135, Tail Boom, bottom shell and roof

-H145 T2, Tail Boom, bottom shell and roof

-H225, Intermediate Structure

-NH90, complete airframe

-Tiger, complete airframe

Fig.1. : EC 135 tail boom structure

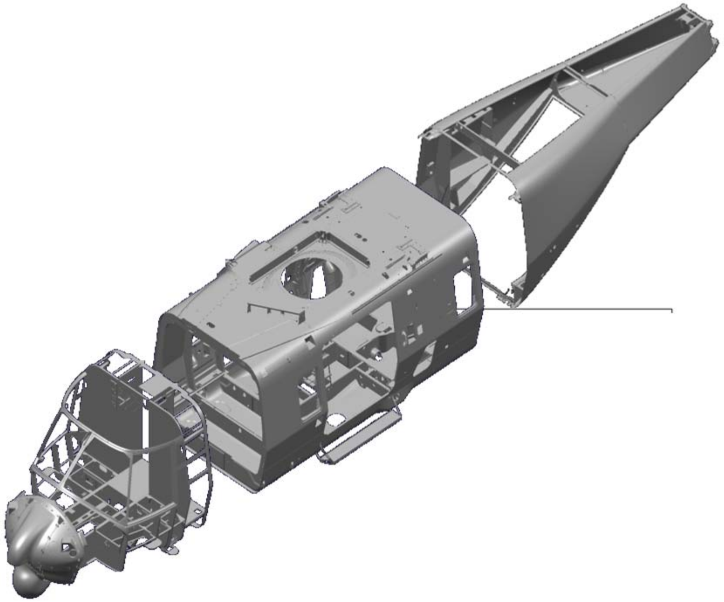
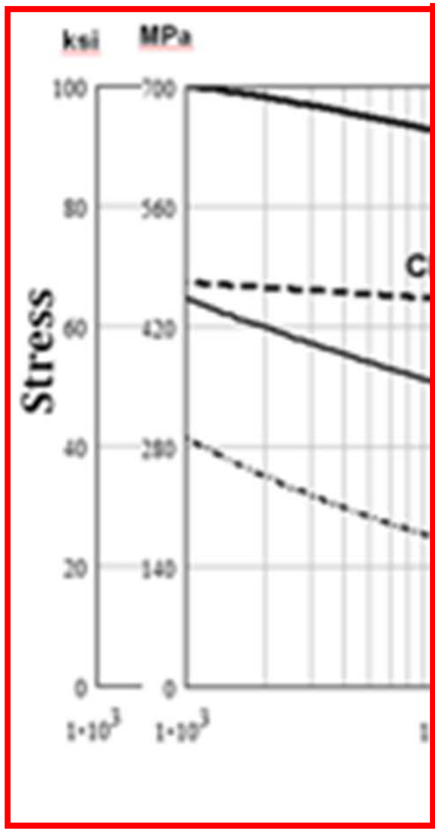


Fig.2. : NH90, fuselage

Introduction, cont‘d



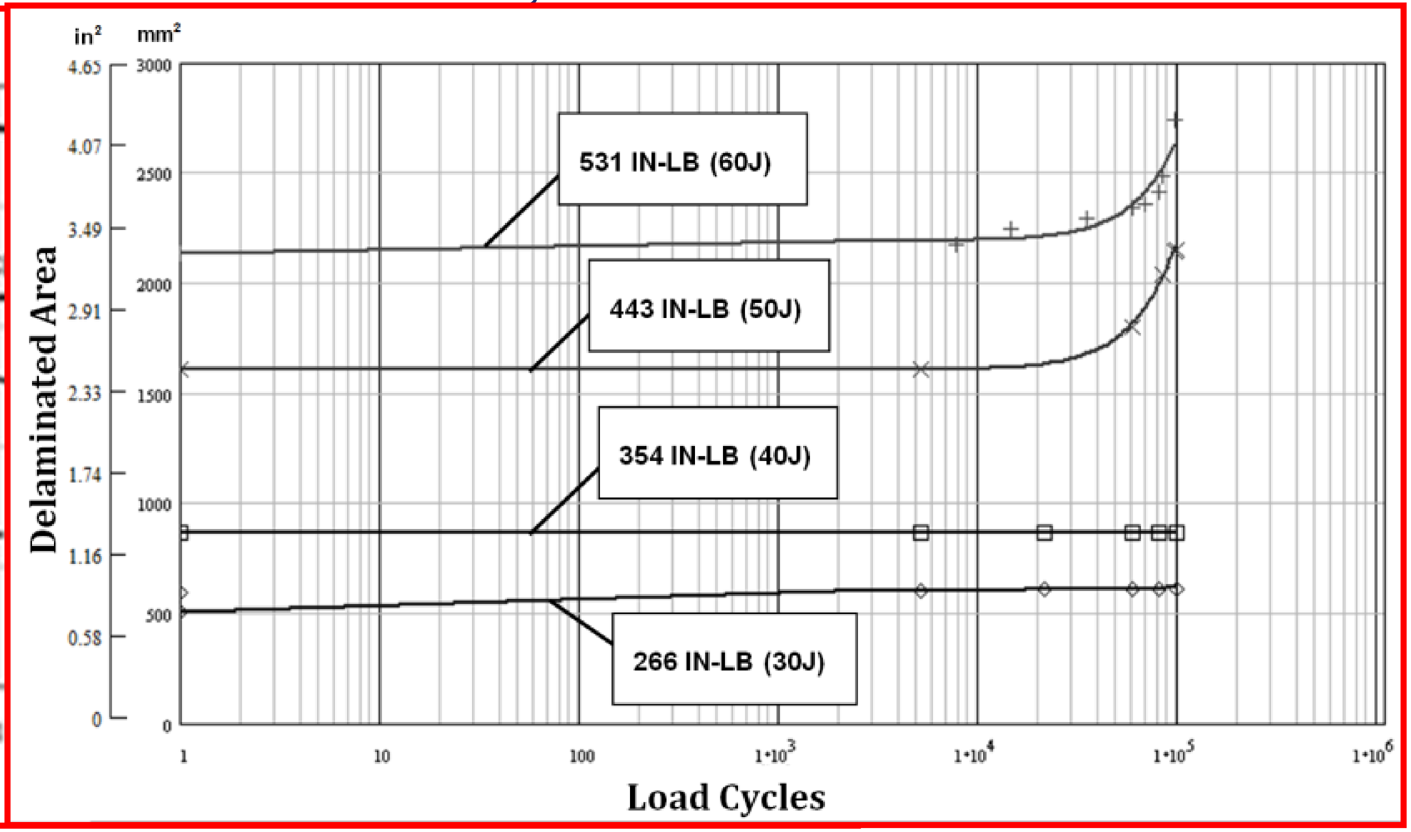


Fig 3: S/n curves

- notched and un-notched coupons
  - Al. 7075
  - CFRP laminate (quasi-isotropic layup)
- stress ratio of R= -1 (R=S_{max}/S_{min})

Fig. 4: Delamination growth/ no growth (in area)

•CFRP, monolith. coupons

•impacted @ different energy levels

•loaded with constant amplitude (% of σ_{CAI})

•stress ratio of R=0.1.

Identification of composite airframe Principal Structural Elements (PSE)

- **Definition of PSE** (acc. to Ref.(1) **:** ***„****a structural element that contributes significantly to the carrying of flight- and ground loads and whose* ***failure can lead to catastrophic failure*** *of the rotorcraft."*

- Failure mode effect and criticality analysis (**FMECA**) is one means to identify composite airframe PSE.

- It is proposed to assume as failure of a PSE its loss of capability to sustain DUL, due to possible in-service damages which led to a partial destruction of the PSE. To regard as failure a complete disappearance of a PSE is not regarded as meaningful.

Identification of composite airframe PSE, cont‘d

Examples for typical composite airframe PSE:

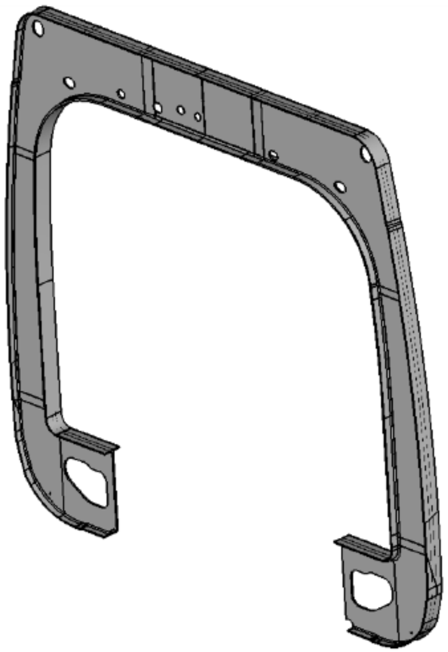


Fig. 5: Typical composite main frame.
(monolithic techno)

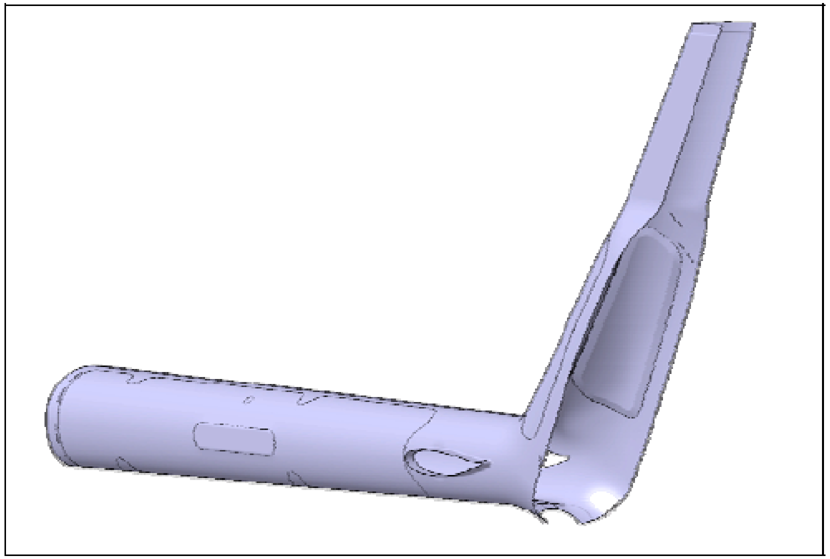


Fig. 6: Typical composite tail boom shell structure.
(sandwich techno)

A method for a threat assessment

1 – Stowed Baggage Impact with Vertical Surface

2 - Stowed Baggage Impact with Horizontal Surface

3 – Dropped Tool Impact

4 – Dropped Part Impact

5 - Fueling Nozzle Impact

6 – Pneumatic Ground Start Coupling Impact

7 – Foot Traffic Impact

8 – Boot Impact

9 - Edge and Corner Impact (dropped panel)

10 - Edge and Corner Impact (struck panel)

11 – Impact with Terrain Objects

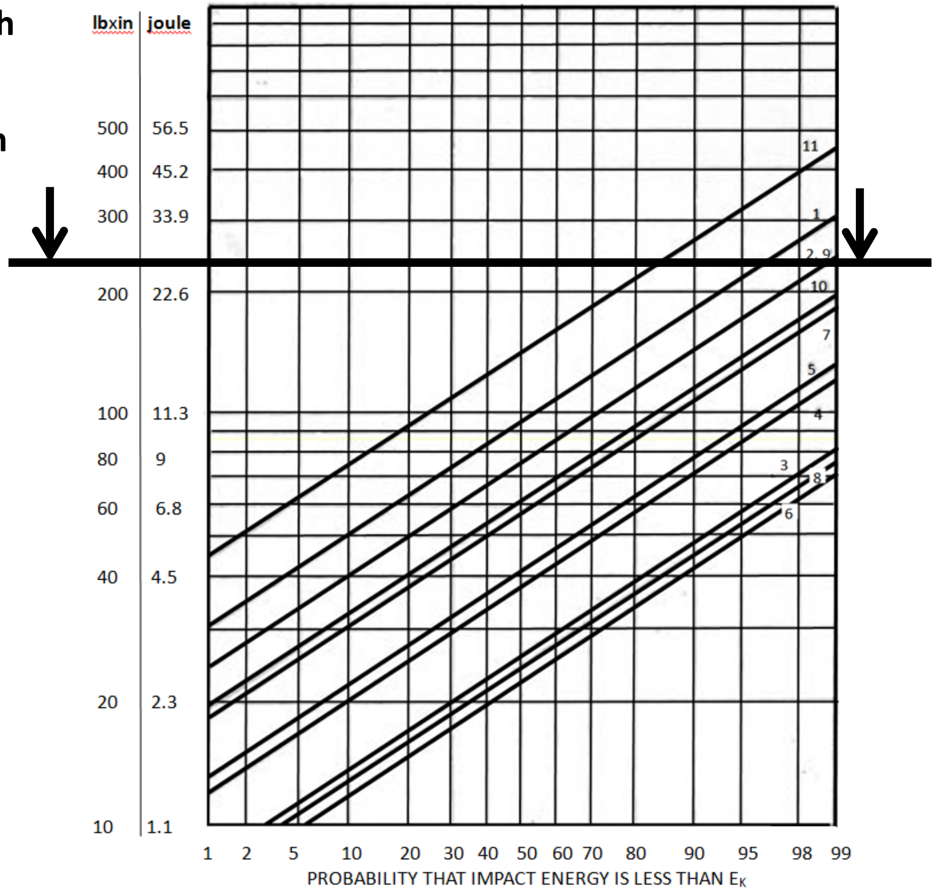


Fig. 7: Possible impact energy threats vs. their probability acc. to Ref. (2).

Assumed realistic impact threat: max. **25J** (AH in-house experience)

A method for a threat assessment, cont‘d

Examples: Assumed threats for a main frame- & a sandwich panel - PSE

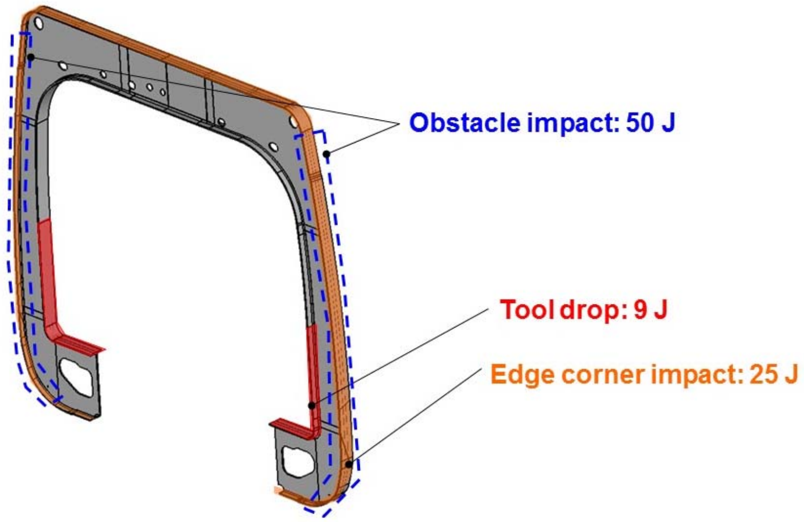


Fig.8: Identified possible threats on a typical composite main frame.

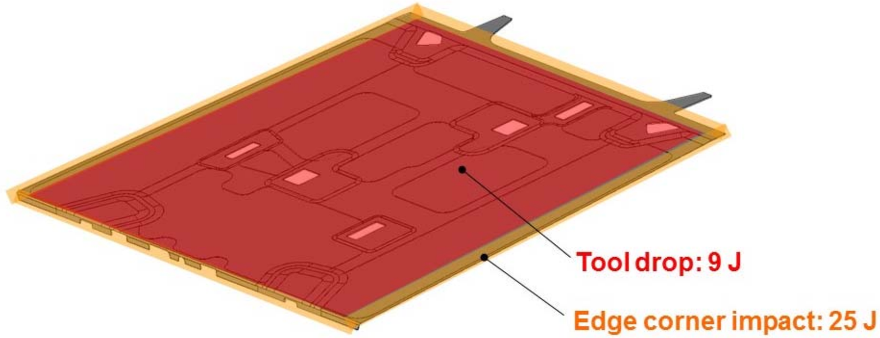


Fig.9: Identified possible threats on a typical composite sandwich panel.

A method for determination of detectability thresholds

- Several dents (>800) were made on diff. composite panels
- Dent depths ranged from 0.05 mm to 1.1mm
- Detailed visual inspection means used to find them (acc. to Ref.3)

Results of an investigation carried out at EADS - IW

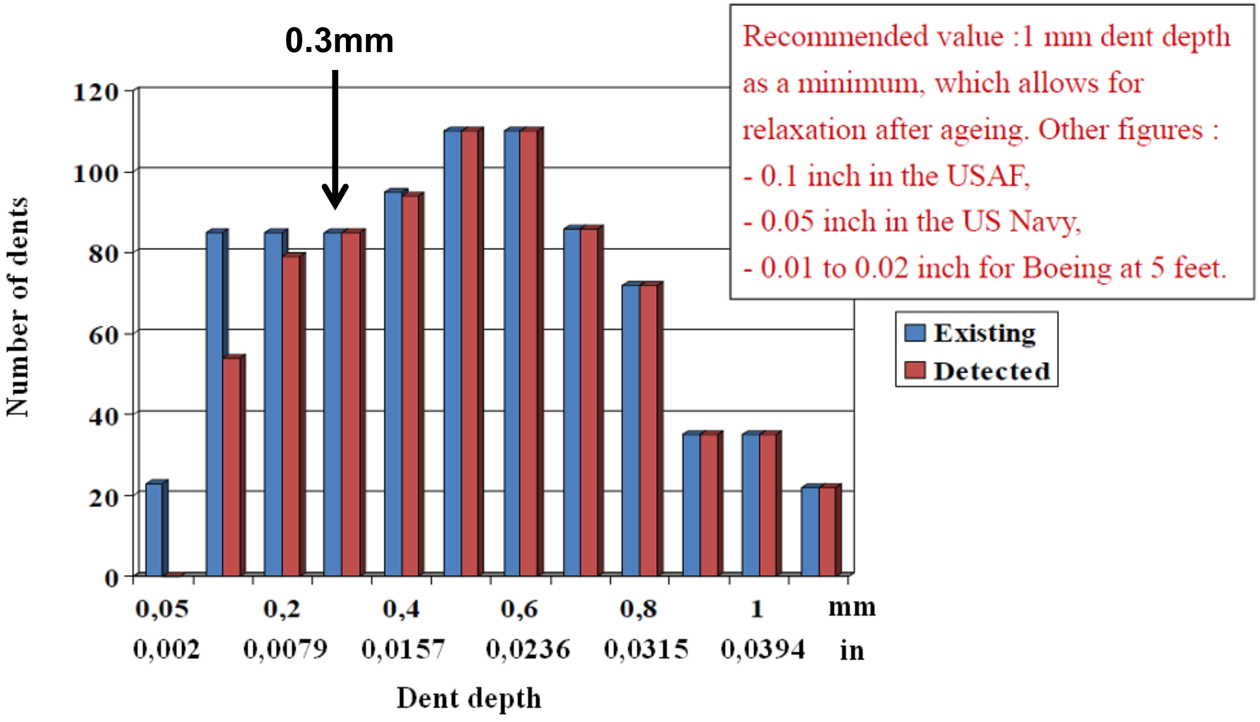


Fig.10: Dent detectability vs. Dent depth

A method for determination of detectability thresholds, cont‘d

- **Dent depth relaxation plays a role for detectability**
- Impact energies: 18J to 23J, dent depth was measured
- 1500h at 70°C/95% r.H., dent depth measured again after exposure
- tested at RT & -40°C at R= -1 & R=0.1, dent depth measured finally

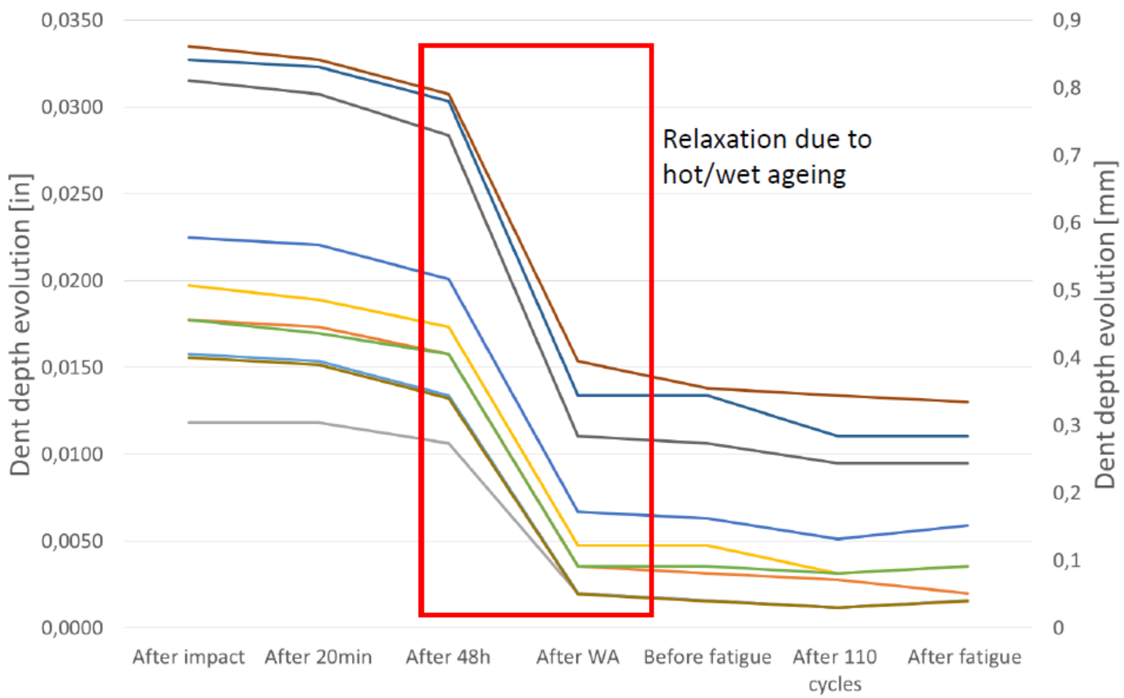


Fig.11: Dent depth relaxation vs. time under hot/wet ageing acc. to Ref. (5).

A method for determination of detectability thresholds, cont‘d

<u>Recommendation for **dent depth visibility**:</u>

- **Relaxation effects** due to **hot/wet ageing** should be considered
- **BVID** zone: from zero **up to 0.3mm** (i.e. **undetectable**)
- **CVID** zone: **> 0.3mm up to 1mm** (i.e. **detectable**):
- **Obvious damage** zone**:** Dent depth **> 1mm** (i.e. **action necessary, e.g. repair**)

Detectability thresholds vs. impact energies

Example: Typical sandwich panel PSE

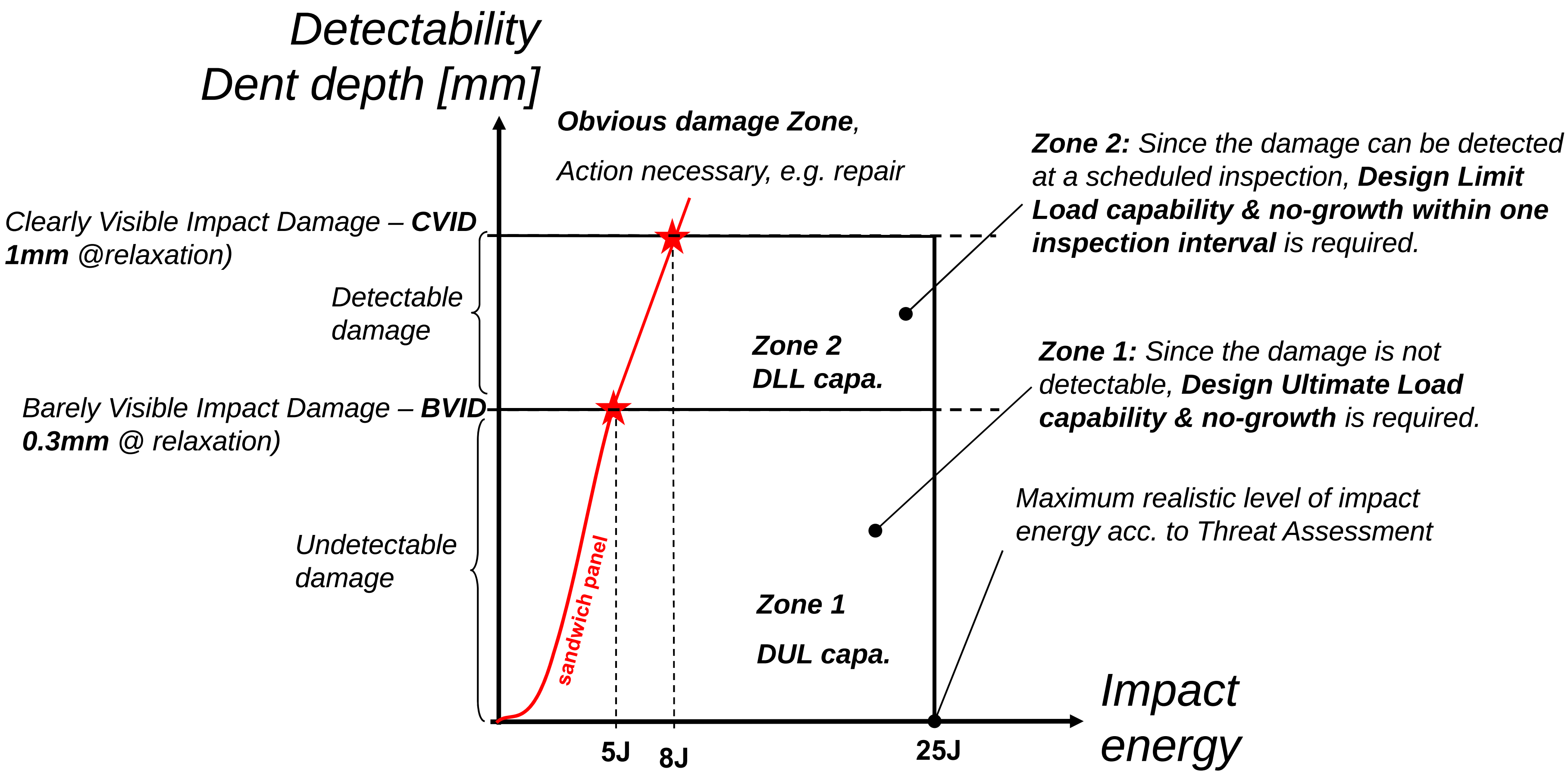


Fig.12: Detecabilty thresholds vs. impact energies,

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A method for showing no-growth behaviour

- Determination of **impact energies for BVID/CVID thresholds** per PSE
- **Impacts done** & **delaminated areas determined** via UT C-Scans
- **Static testing (**Compression after impact testing, σ_{CAI}) of coupons, performed under **hot/wet** conditions
- Determination of **„DUL Strength“** prior to repeated loading

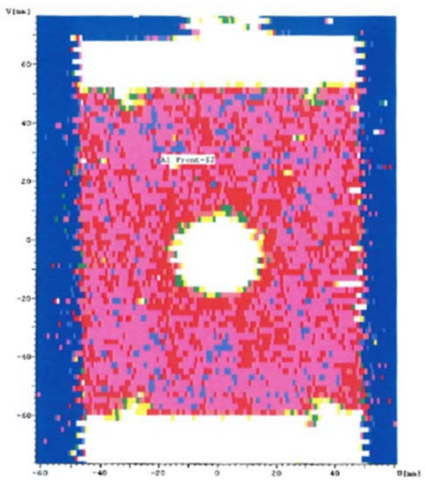

Fig.13: Example Sandwich coupon (CFRP facings & NOMEX honeycomb core), impacted with 5J, picture and C-Scan thereof

A method for showing no-growth behaviour, cont‘d

- **Impacted coupons** loaded under **constant amplitude** (R=0.1) for **10^5 load cycles**
- **No-growth** of **delaminated area checked** periodically with UT C-scans
- **Residual static strength** tested **after fatigue loading**
- **Residual static strength** used to derive **max. allowable strains** for sizing

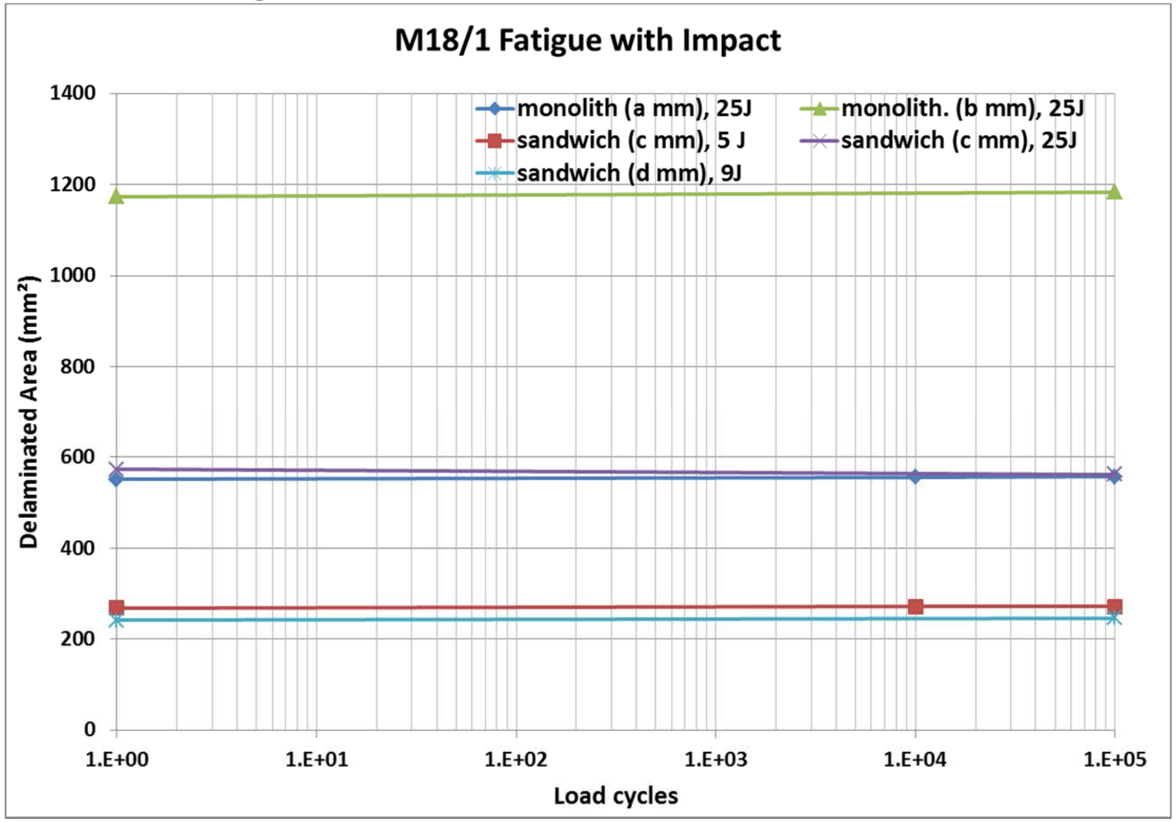

Fig.14: Demo. of Delamination no-growth in area under constant amplitude load cycling

Demonstration of Design Ultimate Load capability, no-growth behaviour & residual strength capability

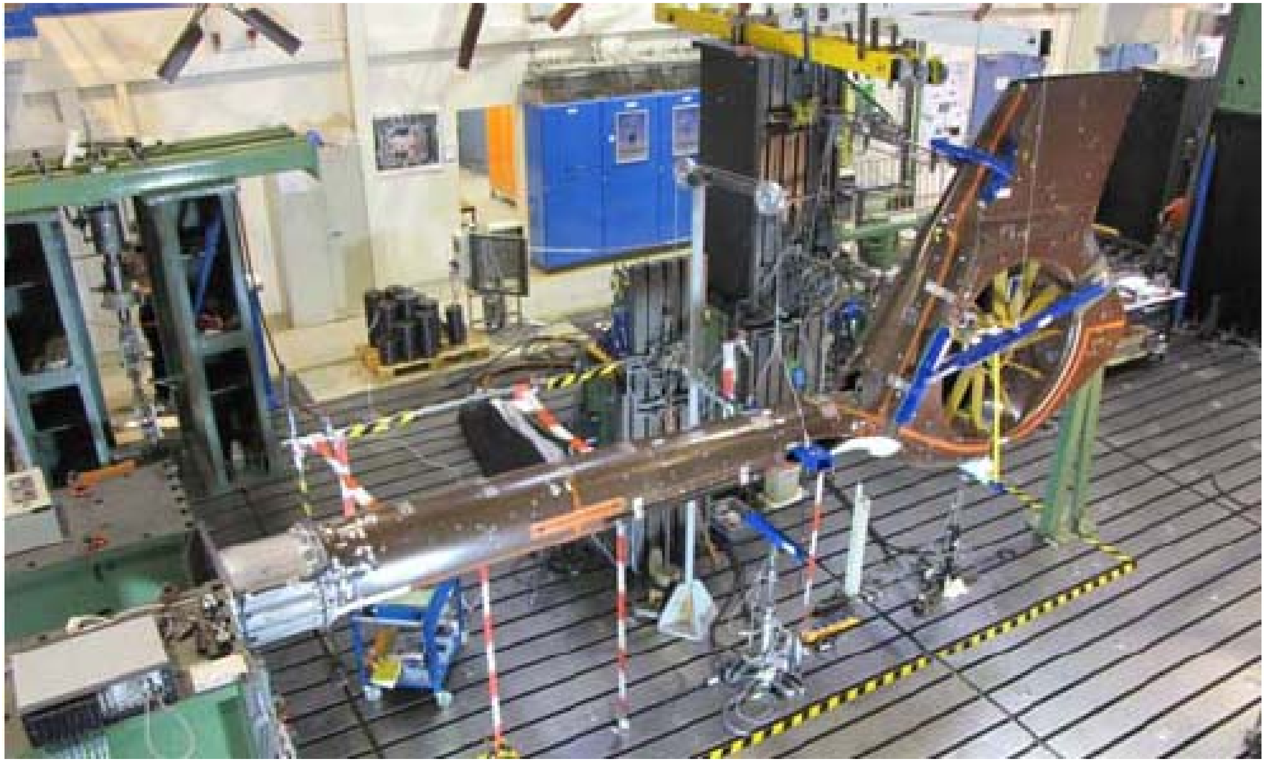

Fig.15: Example, test set up for composite tail boom full scale test.

Demonstration of Design Ultimate Load capability, no-growth behaviour & residual strength capability, cont‘d

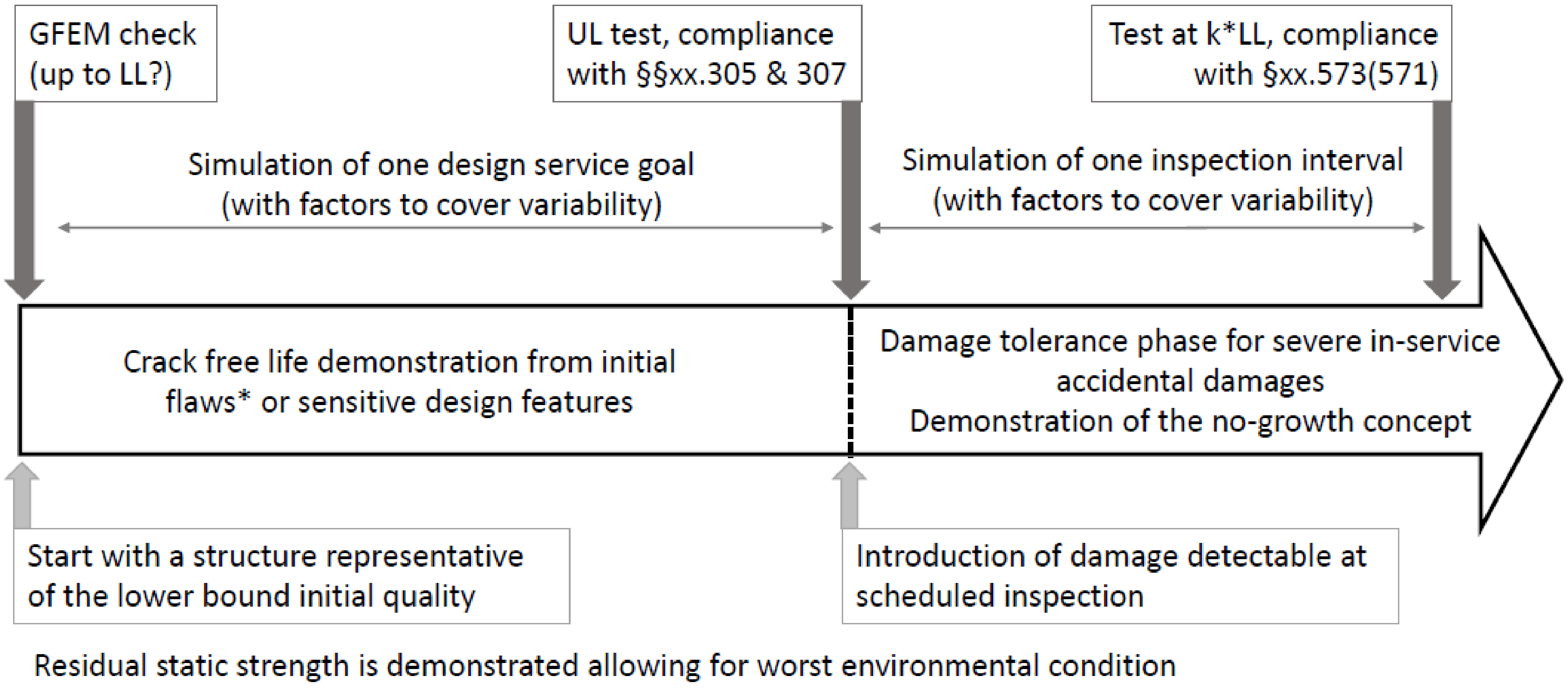

Fig.16: Test sequence for a **new structure, full scale test.**

Demonstration of Design Ultimate Load capability, no-growth behaviour & residual strength capability, cont‘d

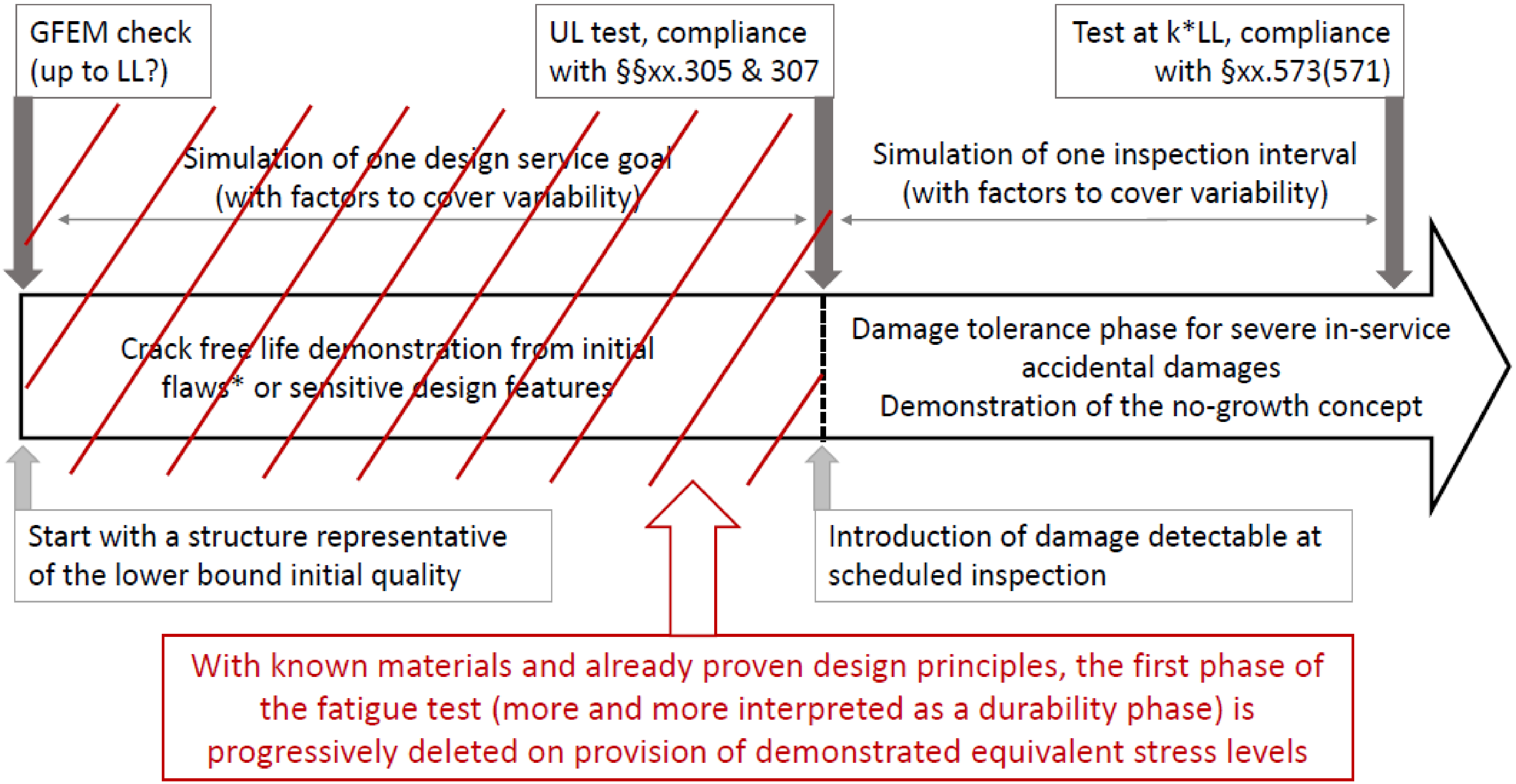

Fig.17: **Alleviated test sequence** for “**similar new structure**” acc. to Ref. (4) & Ref.(7).

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Conclusion

Proposed methodology is based on a **stepwise approach**:

- **Threat assessment** for impact damages
- Derivation of **visibility thresholds** for impact damages
- Application of a **zoning diagram per PSE** for necessary load capabilty evaluation
- Derivation of **design allowables** by CAI, CAI&F and no-growth demonstration on **coupon level**
- **Full scale / component testing** for demonstration of Design Ultimate Load capability, no-growth behaviour & residual strength capability

Thank you for your attention

Questions?