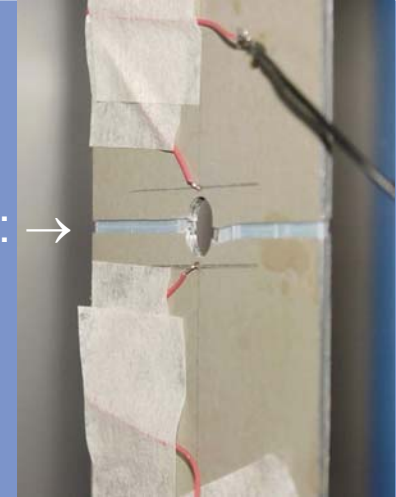


Presented by
Th. Beumler, Airbus

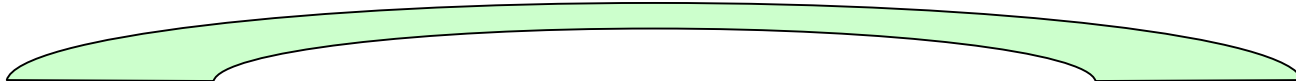
supported by
J. Sinke, TU Delft
B. Borgonje, Airbus

Bridging the gap: →



A contribution of environmental investigations for GLARE[®] riveted joint sizing

Bridging the gap

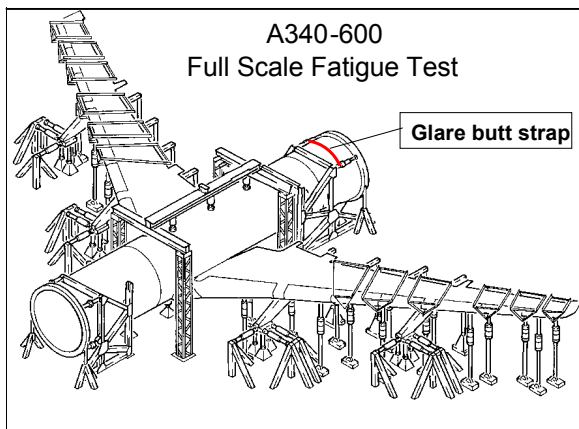


Contents

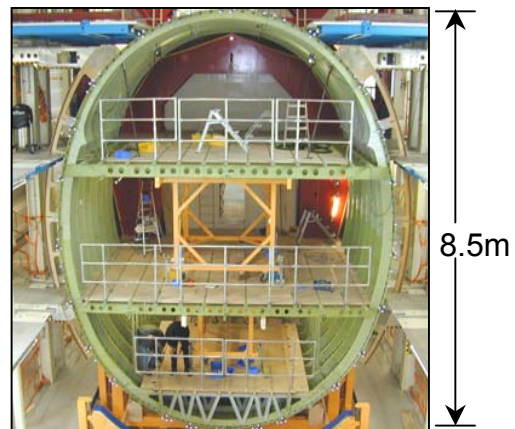
- General information about the outdoor exposure program
- A case study: Residual strength of a riveted joint including ageing considerations

TU Delft / Airbus Outdoor Exposure Program

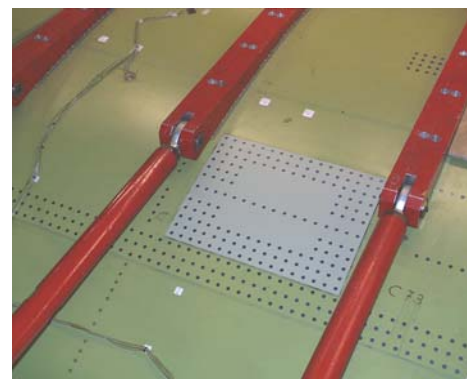
Investigation of 2 Airbus full scale structures under consideration of environmental influences:



GLARE2B Butt Strap



GLARE4A Repair on GLARE4 Skin



Targets of outdoor exposure program:

- Investigate the moisture diffusion in fiber prepregs through holes
 - ▶ in case of accelerated ageing (environmental chamber)
 - ▶ in case of outdoor exposure (tropic environment)
- Investigate under environmental influences and variable temperature
 - ▶ all static failure modes
 - ▶ fatigue crack initiation
 - ▶ fatigue crack propagation
 - ▶ residual strength under tension and compression
- Discuss the relevance of knock-down factors and recommend procedures for future tests.

TU Delft / Airbus Outdoor Exposure Program

Specimens involved:



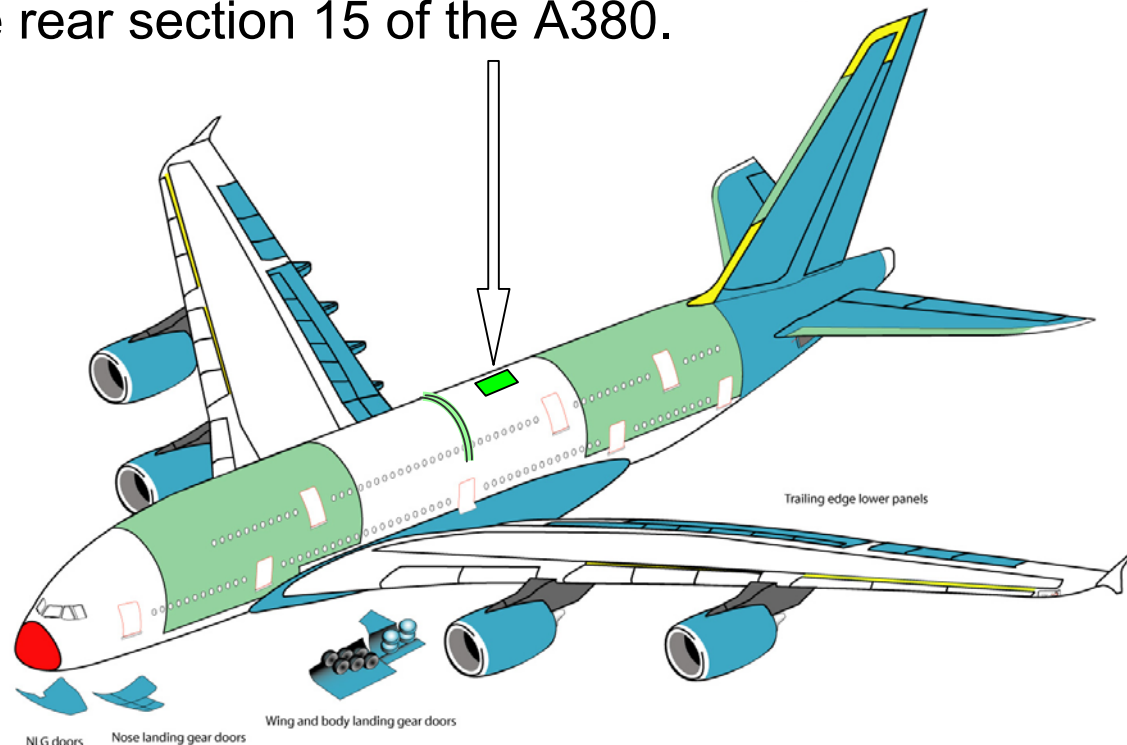
direction of solar radiation

specimen type	GLARE2A / butt strap	GLARE4A / repair	remarks
joints			
blunt notch			
bearing strength			fasteners to be removed after exposure
rivet strength			
compression filled hole			
rivet pull through strength			
moisture reference specimens			GLARE3, riveted specimen shown
riveted repair panels			
bonded repair panels			bondline between skin and patch unprotected
door corner cut out specimens			edges unprotected
tau gamma specimens			fasteners to be removed after exposure

Topic of ICAF 2009 presentation:

Justification of riveted repair (skin and patch GLARE4A-5/4-.4 ssc, 5.6mm ASNA 2026 bolts) for residual strength.

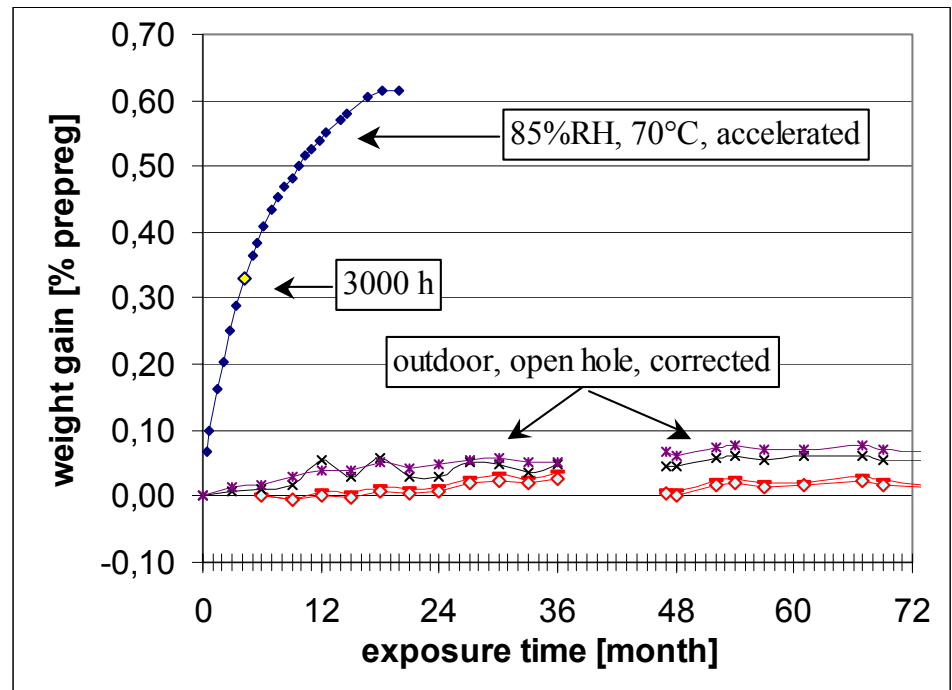
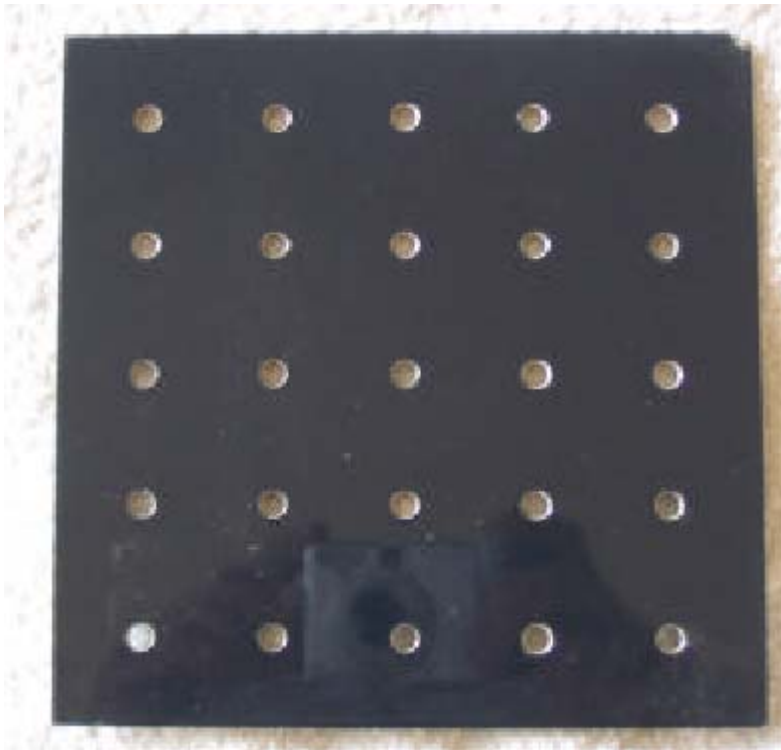
Loads and design of the repair are representative for an assumed GLARE skin in the rear section 15 of the A380.



Moisture Reference Specimens

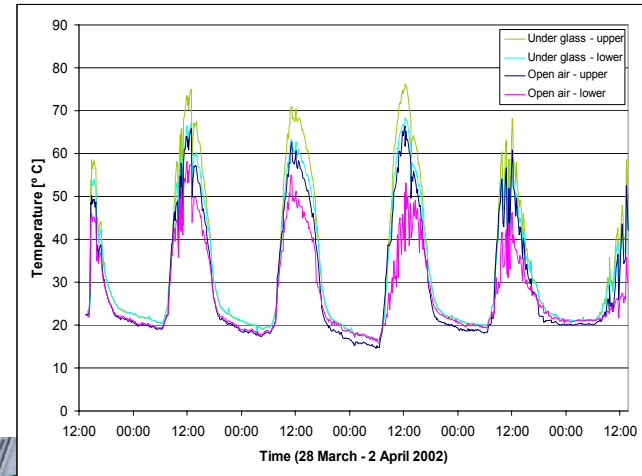
first compromise

- MRS specimens covered by plexy glass, ASTM G24-97.
- Much less moisture absorbed in Australia than after 3000h ageing in 85%RH/70°C humid air.



Mechanic Specimens

- Mechanic specimens exposed to open sky. Photos from 2003:



Mechanic Specimens

- Riveted joints in 2003



Compromises

Because loading and exposure can not be superposed, a series of compromises has to be accepted for the residual strength investigation.

Aircraft:

- operation until crack initiation → potential diffusion in prepreg through holes
- operation after crack initiation → potential diffusion in prepreg through cracks

RS test, option a):

- 1) cycle specimen to pre-defined fatigue crack length
- 2) outdoor exposure with fatigue cracks → potential diffusion through cracks
- 3) RS test: prepreg in vicinity of fatigue cracks potentially wet

RS test, option b):

- 1) outdoor exposure without fatigue cracks → potential diffusion through holes
- 2) cycle specimen to pre-defined fatigue crack length
- 3) RS test: prepreg in vicinity of fatigue cracks potentially dry

Decided: Investigation of both options.

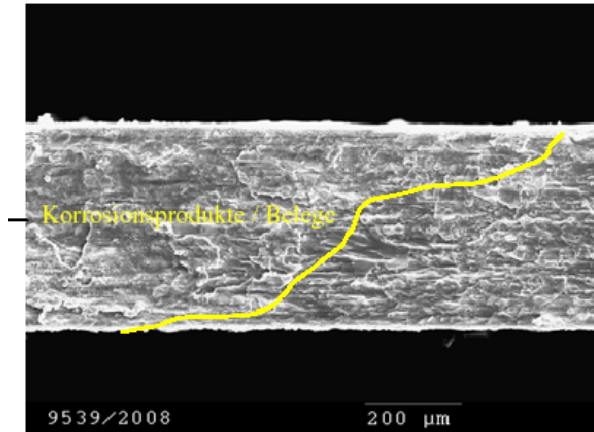
Compromises

Manufacturing sequence mechanic specimens:

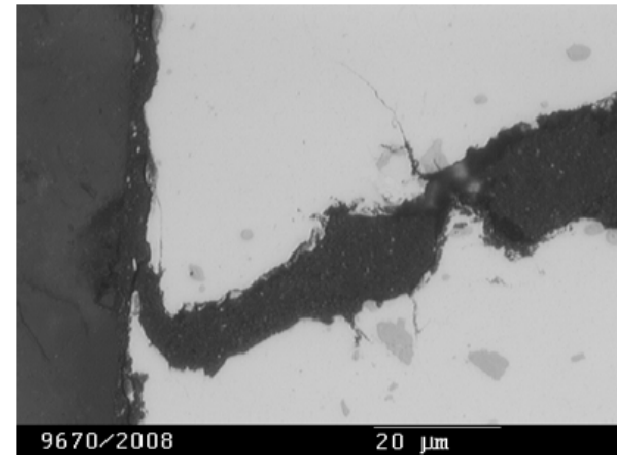
- 1) Painting
- 2) Drilling
- 3) Fastener installation without anti fretting compound (GLARE4A: clearance fit).

→ Access of moisture and rain to fastener holes.

→ Corrosion after 6 years outdoor exposure.



9539/2008 gesputtert
Bild 14: Äußere Aluminium-Lage, rechte Bohrungsseite, Korrosionsprodukte/Belege auf der Bruchfläche im Bereich 1mm von der Bohrung entfernt

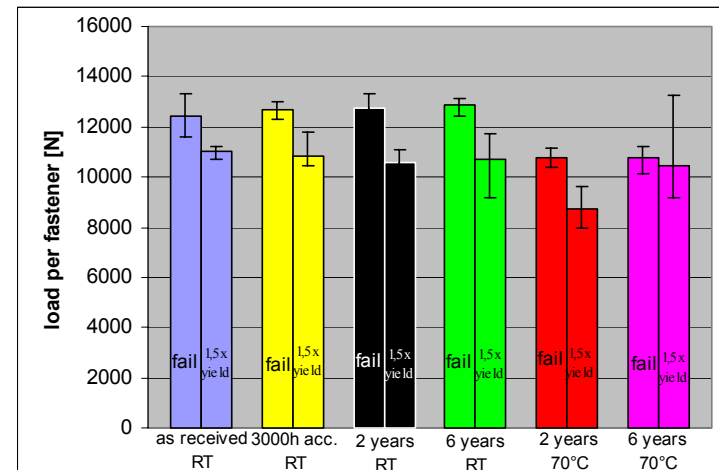
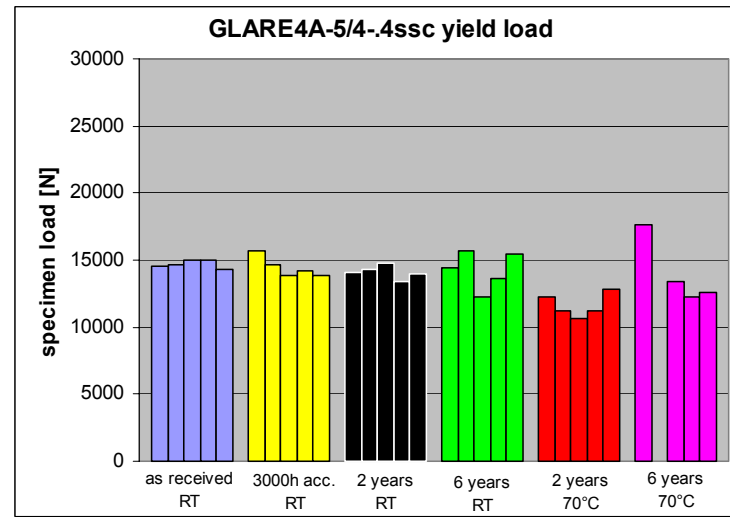
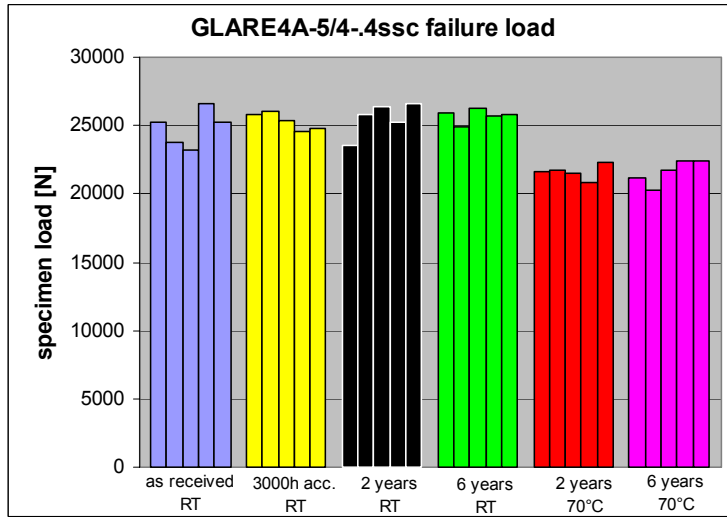


9670/2008 1000:1
Bild 24: Row 3, rivet 1, Korrosionsangriff in der Bohrung und im Riss, Det. aus Bild 23

Outdoor Exposure Results supporting Repair Justification

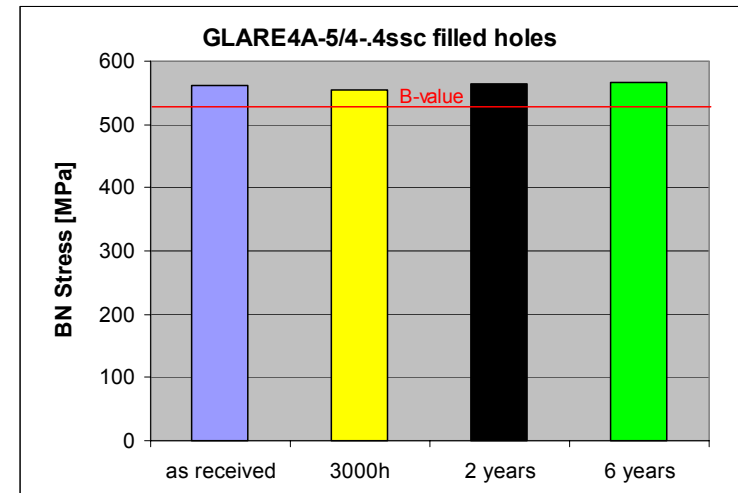
Rivet Strength

- Static tests, i.e. without fatigue cracks; bearing loads.



Filled Hole Tension

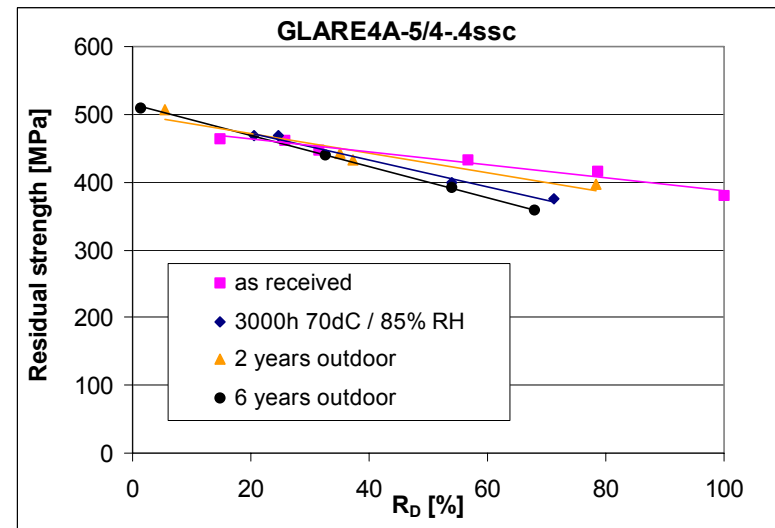
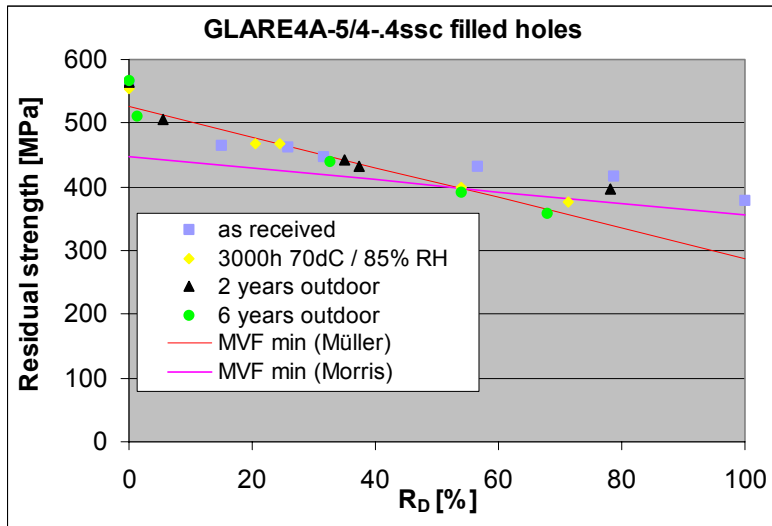
- BN results, i.e. without fatigue cracks; by-pass loads.



No ageing influence.

Filled Hole Tension

- Residual strength results, i.e. with fatigue cracks.



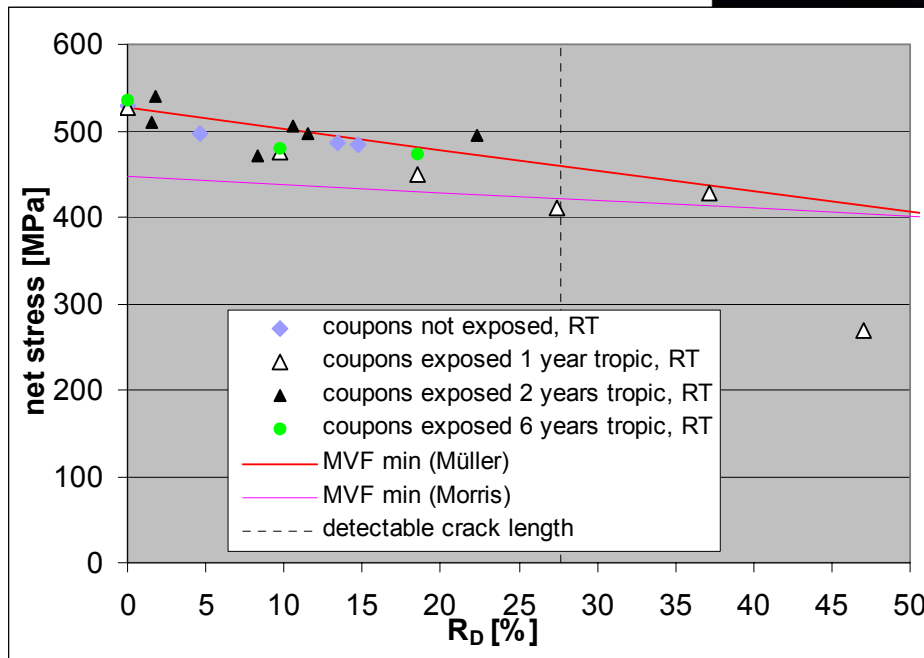
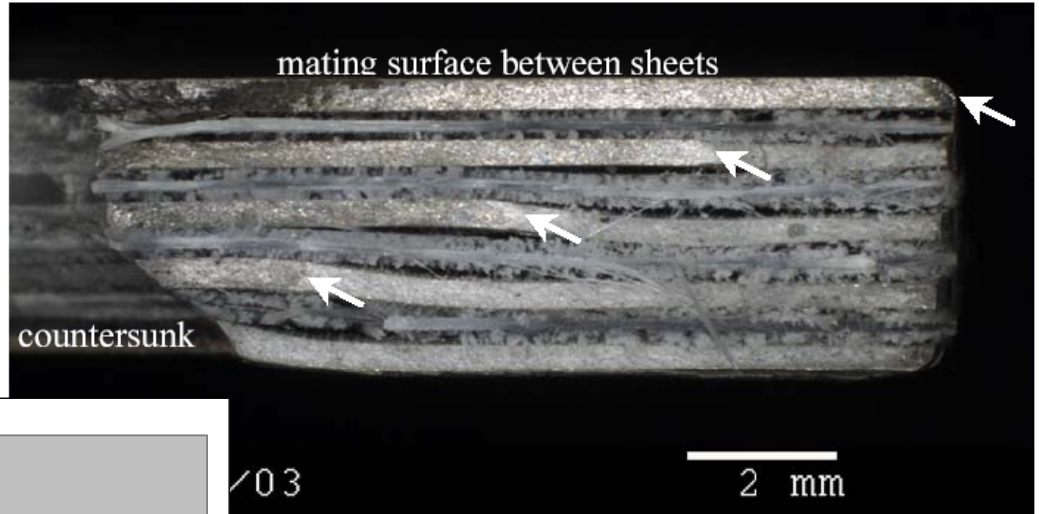
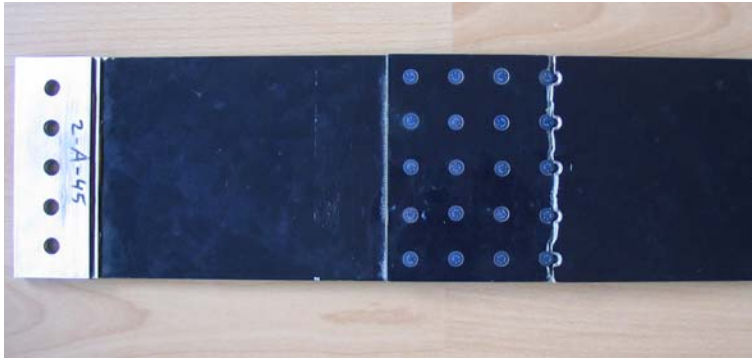
- All results close to design curves.

Different slopes ?



Riveted Joints

- Combined bearing + by-pass stress, secondary bending.

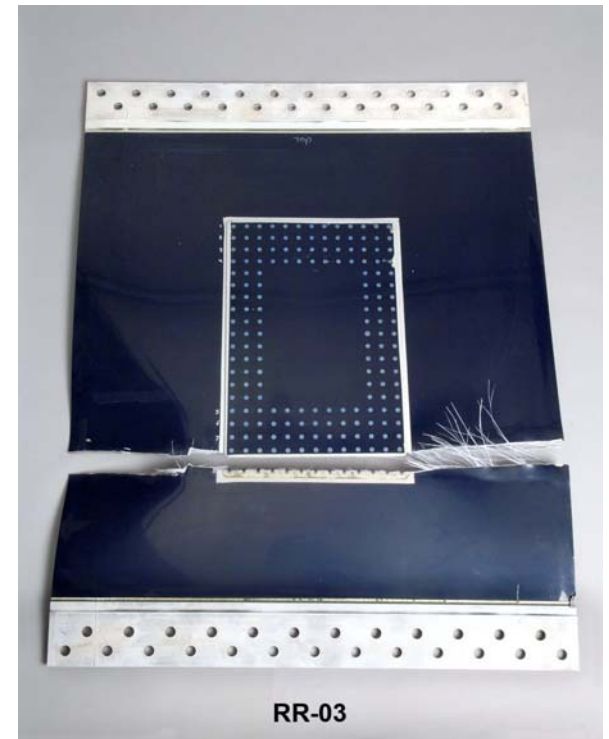
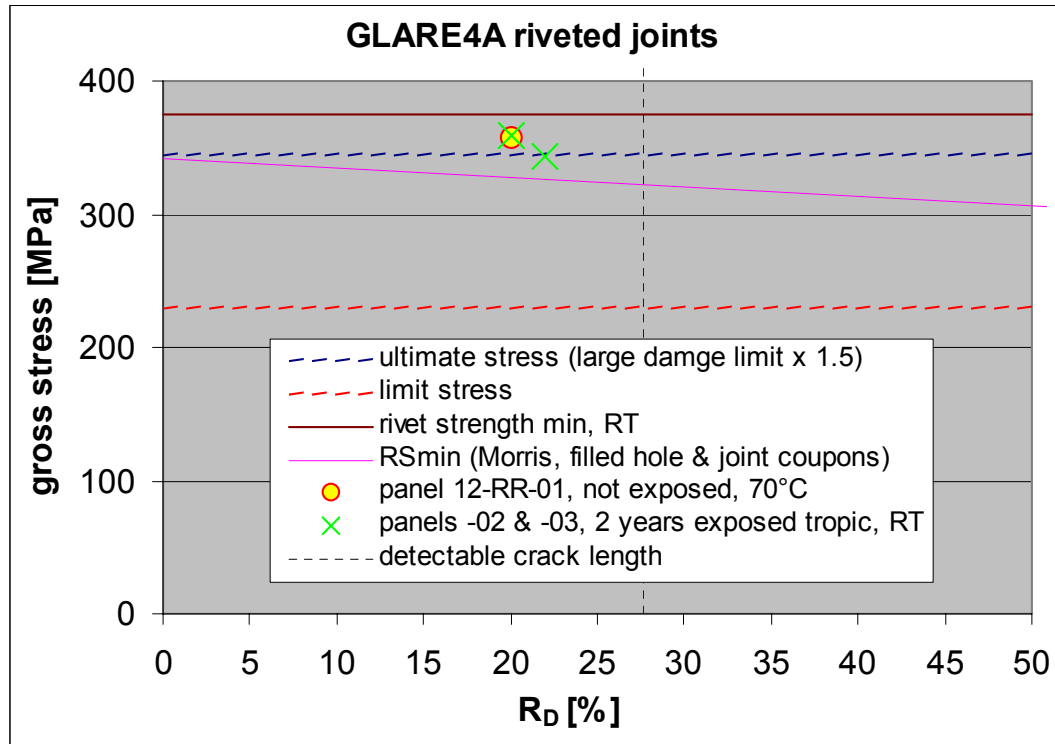


- All results except one close to design curves.

Riveted Joints

Summary including panel results (gross stress shown).

Considered design criterion for skin: max tensile limit load stress 230 MPa, failure criterion Large Damage Capability and Repairability:



Some Conclusions related to Residual Strength

- The loads determining Residual Strength on the rear upper fuselage appear at:
 - ▶ room temperature (landing case)
 - ▶ below room temperature (gust case during cruise)
- therefore the KDF for RS related to Temperature is 1.0
- Outdoor exposure tests show that the KDF for RS related to Environmental Exposure is 1.0 as well, if the Design Curve evaluated by Morris is applied.

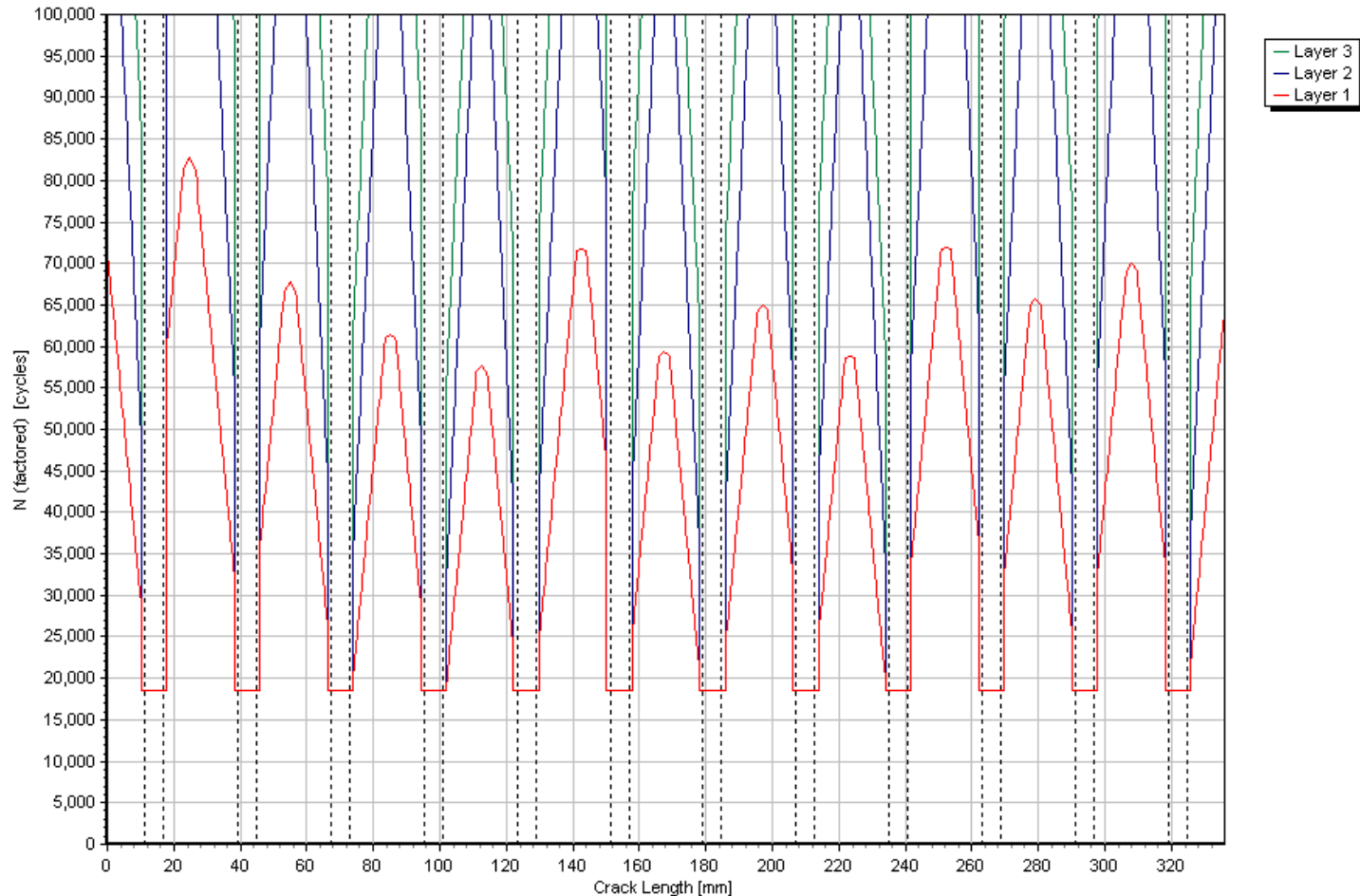
Some Conclusions related to Residual Strength

- A moisture content and distribution in GLARE around rivet holes similar to that obtained after 6 years exposure in Queensland can be reached as follows:
 - ▶ 9500 hours in an environmental chamber at 30°C / 70% RH
- However, for none of the discussed test series it is necessary to simulate ageing through exposure in an environmental chamber.
- Care has to be taken for the interpretation of test results as soon as corrosion is involved.

Riveted Joint Fatigue Strength Justification

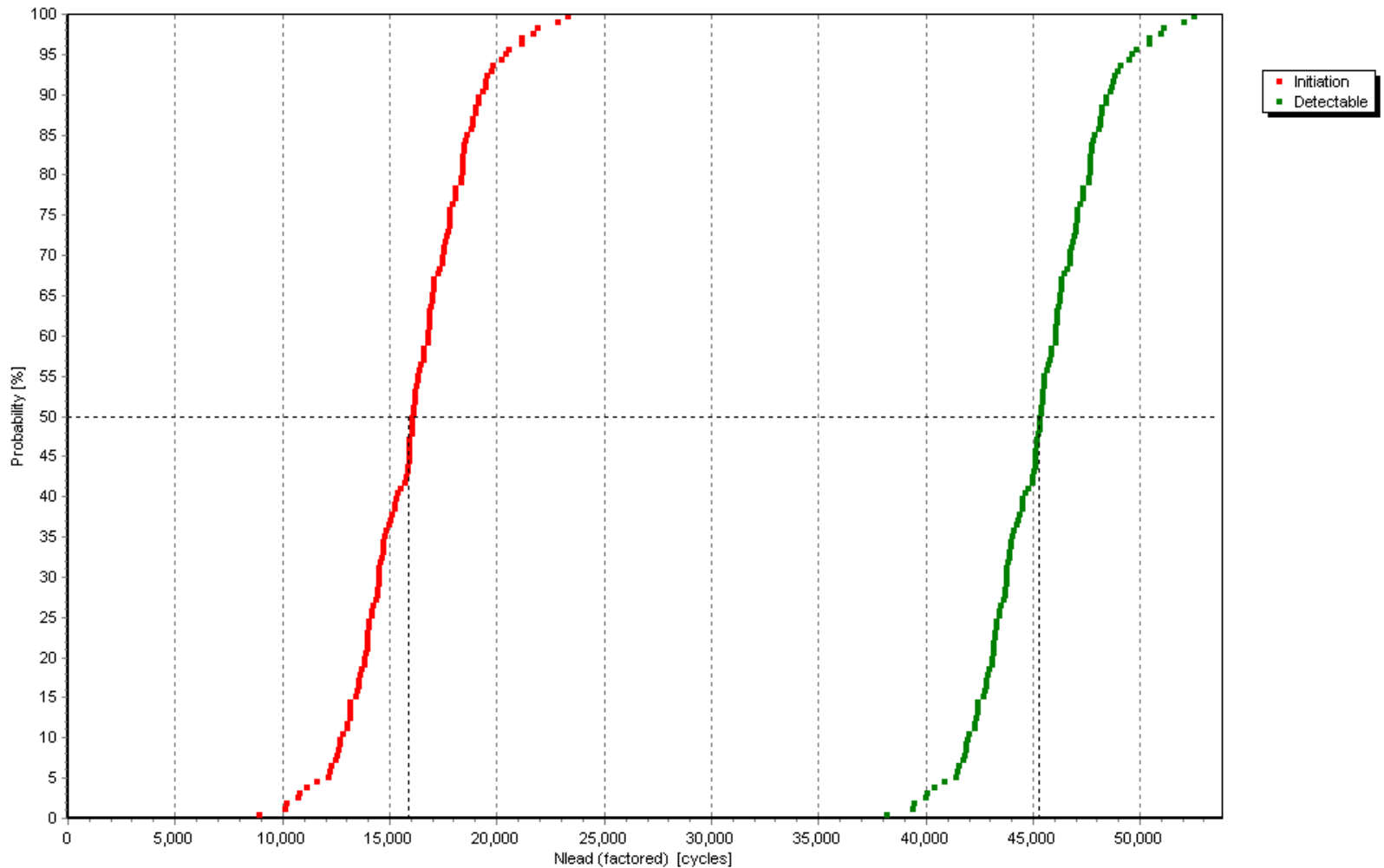
Fatigue strength justification using the TU Delft / Airbus tool „FML F&DT Toolbox“, factorised results:

- One of 150 MSD calculation scenarios, 12 fastener holes in a row:



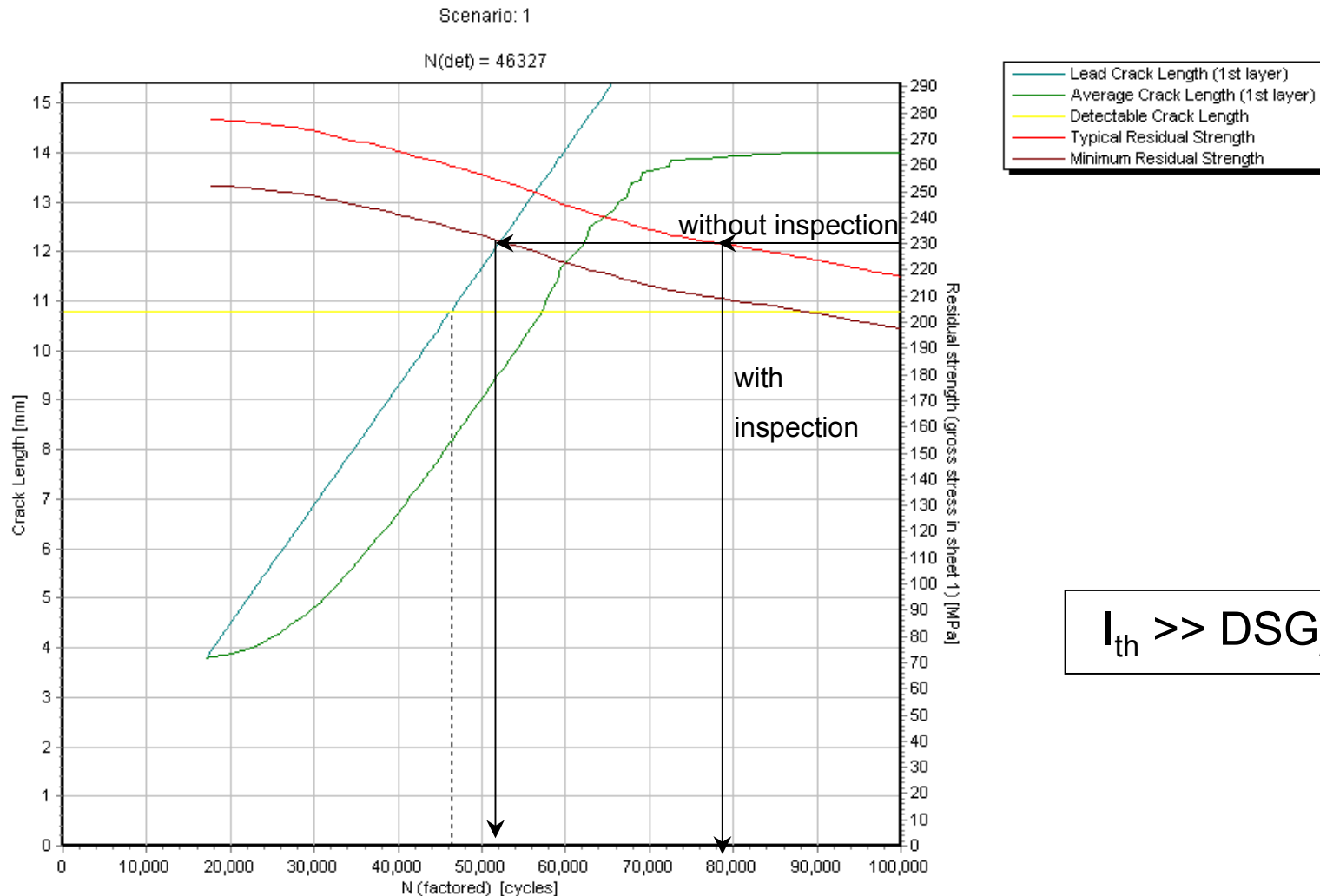
Riveted Joint Fatigue Strength Justification

- MSD Distributions for CI and N_{det} (factorised):



Riveted Joint Fatigue Strength Justification

- Justified by full scale test Megaliner Barrel, factorised results:



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