



Lufthansa Technik

More mobility for the world



Dr.-Ing. Christian Sauer

**Lufthansa Perspective on Applications &
Field Experiences for Composite
Airframe Structures**

Agenda

Introduction

Business Unit ARC - Capabilities

Damage of Composite Structures – Operational Experience

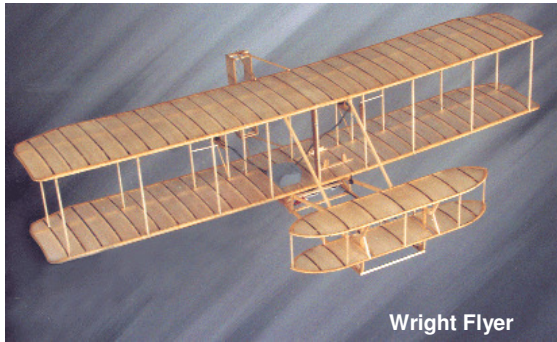
Repair of Composite Parts

Composite Repair Examples

Introduction

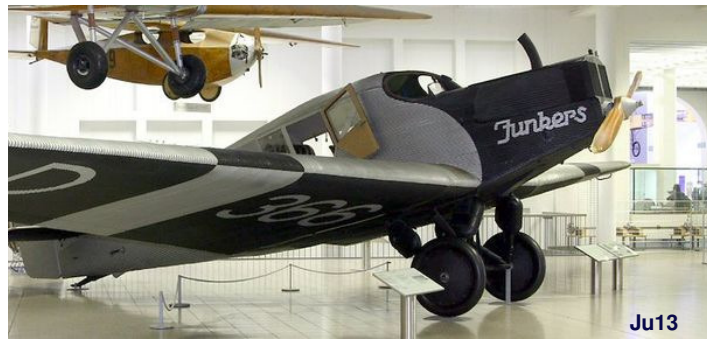
The industry faces another giant leap....

Wood & Linen



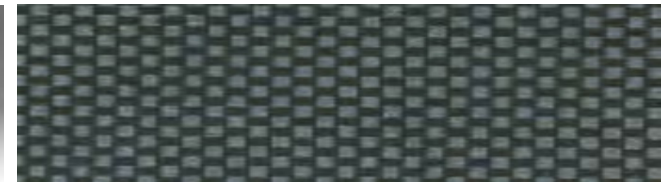
Wright Flyer

Aluminium Alloys



Ju13

CFPR



B787

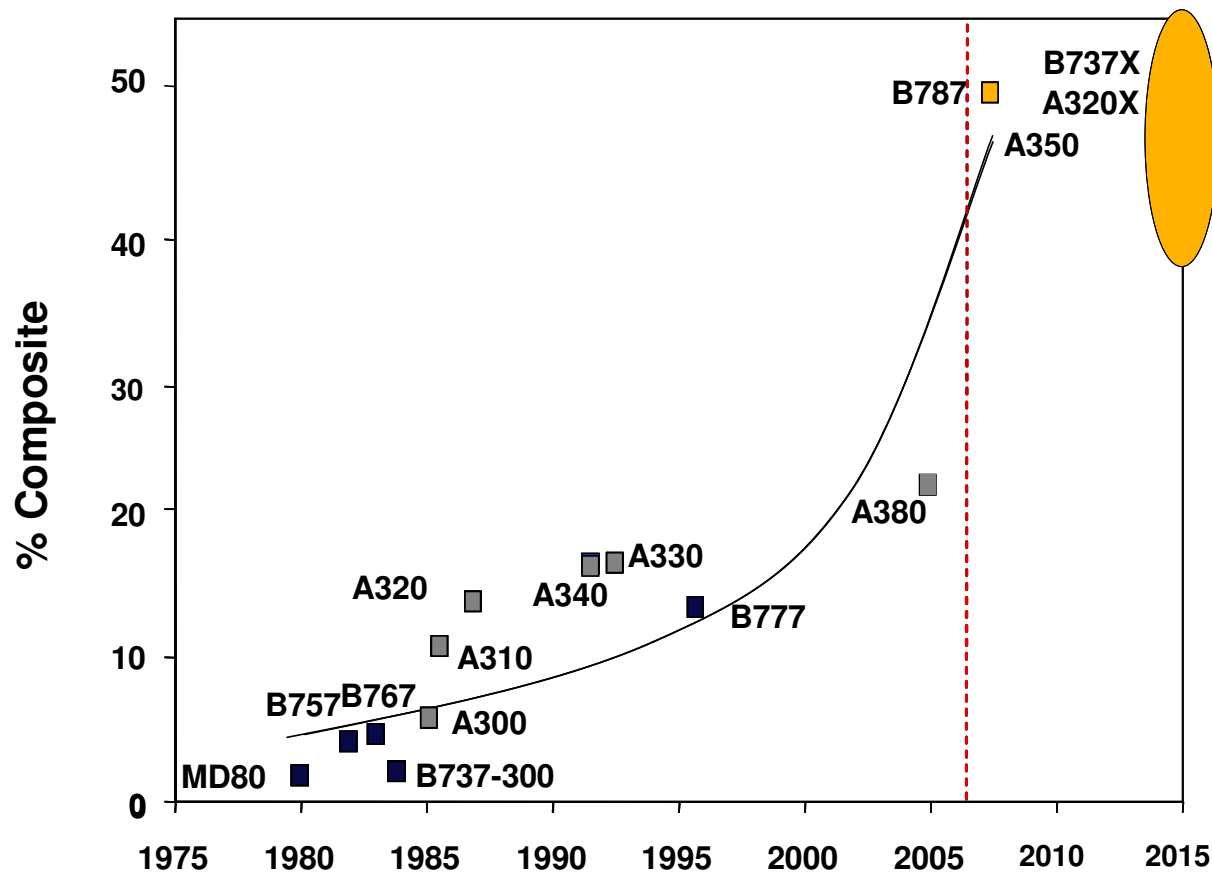
since 1903

since 1919

from 2009/2010

Introduction

Development of Composite Usage



All manufacturers will increase their usage of CFRP and other composite materials



Challenges for Maintenance, Repair and Overhaul because established processes might not work any more



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ARC® Capability

The right stuff



Fan Thrust Reverser

- CFM56-3, -7
CFM56-5A, -5B, -5C
- CF6-50, -80C2
- CF34-3
- V2500-A1, -A5, -D5
- PW2000, PW4000
- Trent 500
- Trent 700
- Trent 900*



Inlet Cowl Fan Cowl

- CFM56-3, -7
CFM56-5A, -5B, -5C
- CF6-50, -80C2
- CF34-3
- V2500-A1, -A5, -D5
- PW2000, PW4000
- Trent 500
- Trent 700
- Trent 900*
- RB211
- JT9D-7R4



Radomes

- A300, A310
- A318, A319
- A320, A321
- A330, A340
- A350*
- A380*
- 737, 747
- 757, 767
- 787*
- MD11
- CRJ

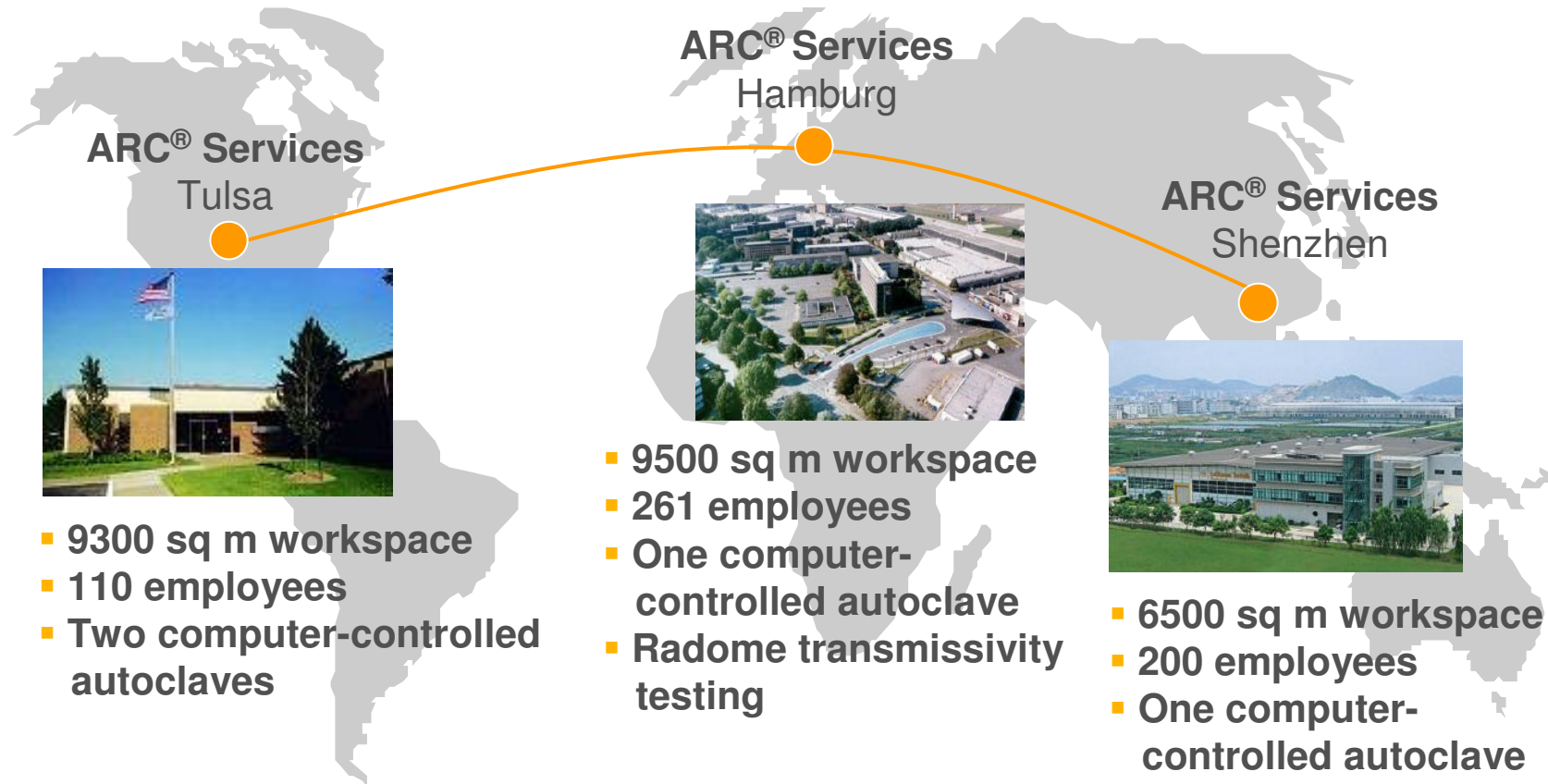


Flight Controls

- A300, A310
- A318, A319
- A320, A321
- A330, A340
- A350*
- A380*
- 737, 747
- 757, 767
- 787*
- MD11

ARC® Global Network

Each of our facilities is equipped with the latest technology

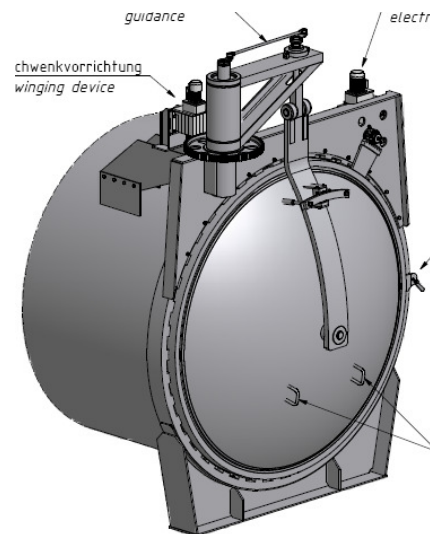


ARC®

Fit for the future....

ARC Shopfloor extension in Hamburg currently ongoing (completion Dec. 2009)

- New computer controlled autoclave (5m diameter x 6m length, up to 16bars)
- Logistics center with 1400 m² floor area and 11,5 m lift height
- Composite repair shop with 740 m² floor area
- Parameters of buildings & equipment fit for composite repairs of very large components, e.g. TRENT 900 and A380



Airline Support Team AST®

The Flying Doctors

Damages on nacelles and composites may significantly affect your aircraft operation:

- Unexpected aircraft downtime (AOG)
- Shop turn around for nacelles and composites
- Requirement of exchange units (major components)
- Restrictions in aircraft operation



Lufthansa Technik's AST® Nacelles & Composites with its vast know-how and maintenance experience is prepared to provide fast and reliable repair solutions on-site whenever/wherever possible to avoid aircraft downtime.

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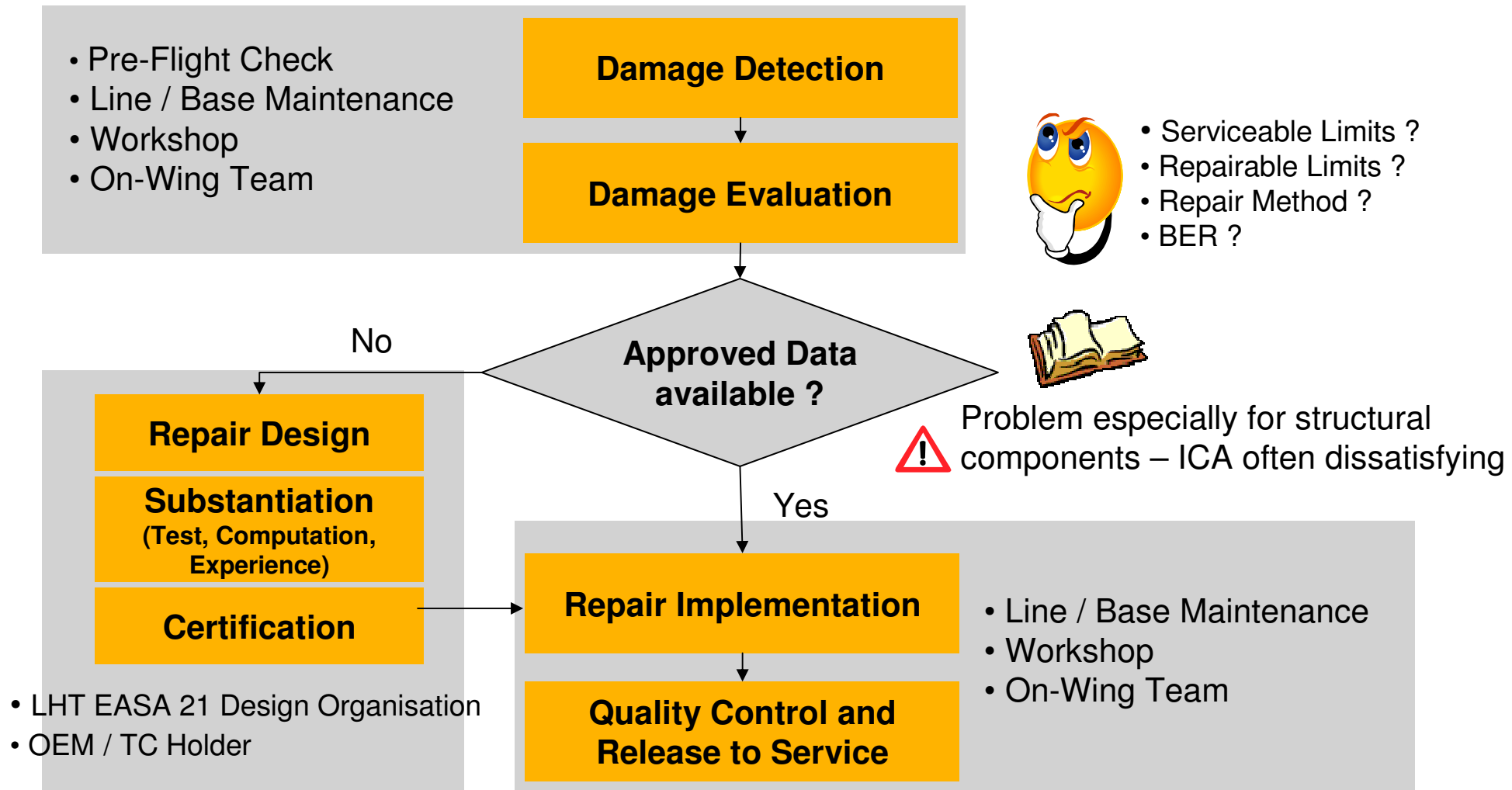
Damage of Composite Structures – Operational Experience

Repair of Composite Parts

Composite Repair Examples

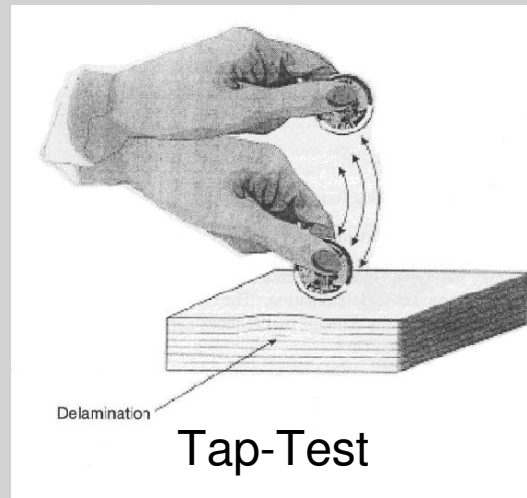
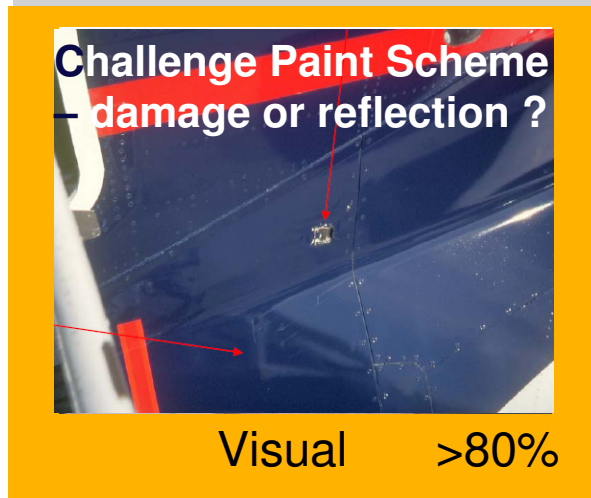
Damage of Composite Structures

Schematic Repair Procedure

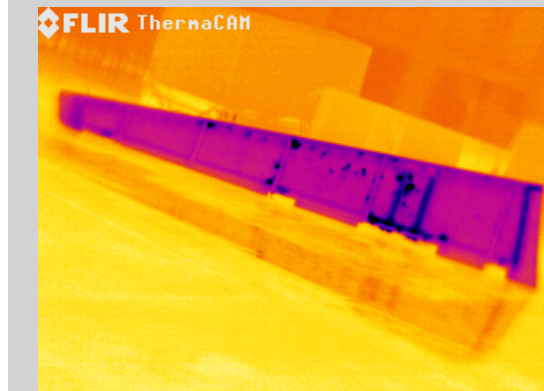


Damage of Composite Structures

Inspection and Detection



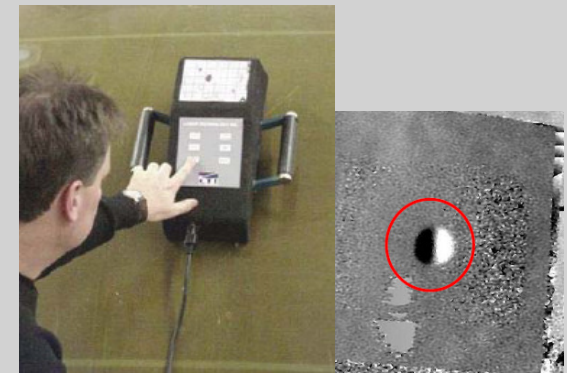
Ultrasonic



Thermography



IR Lockin Thermography

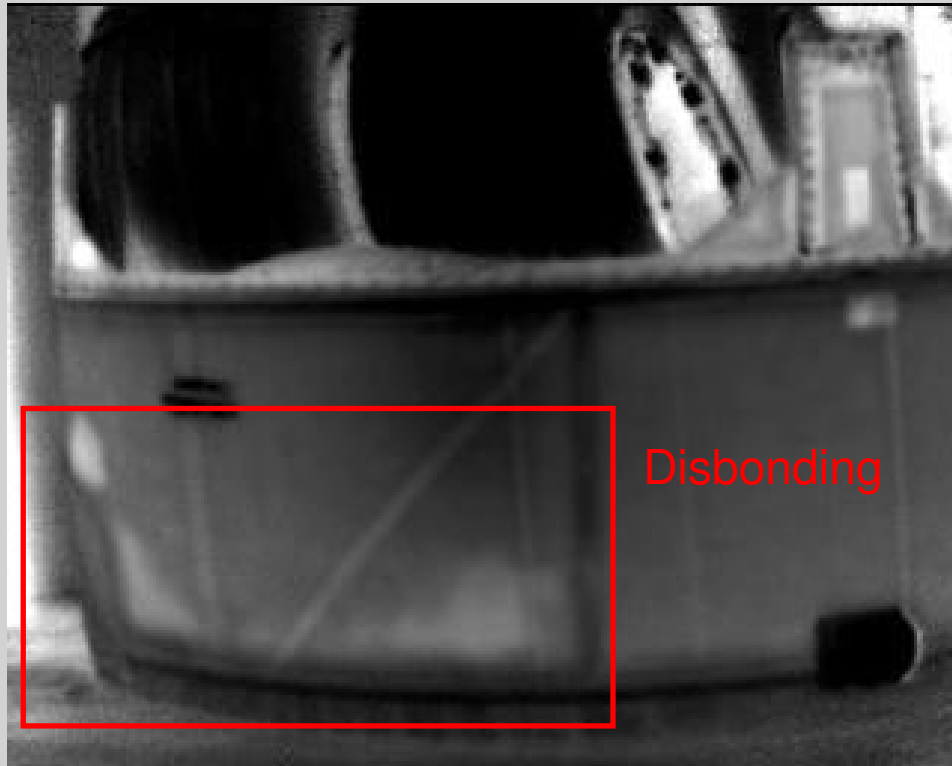


Shearography

Damage of Composite Structures

Inspection and Detection

LHT In-service evaluation of IR Lockin Thermography

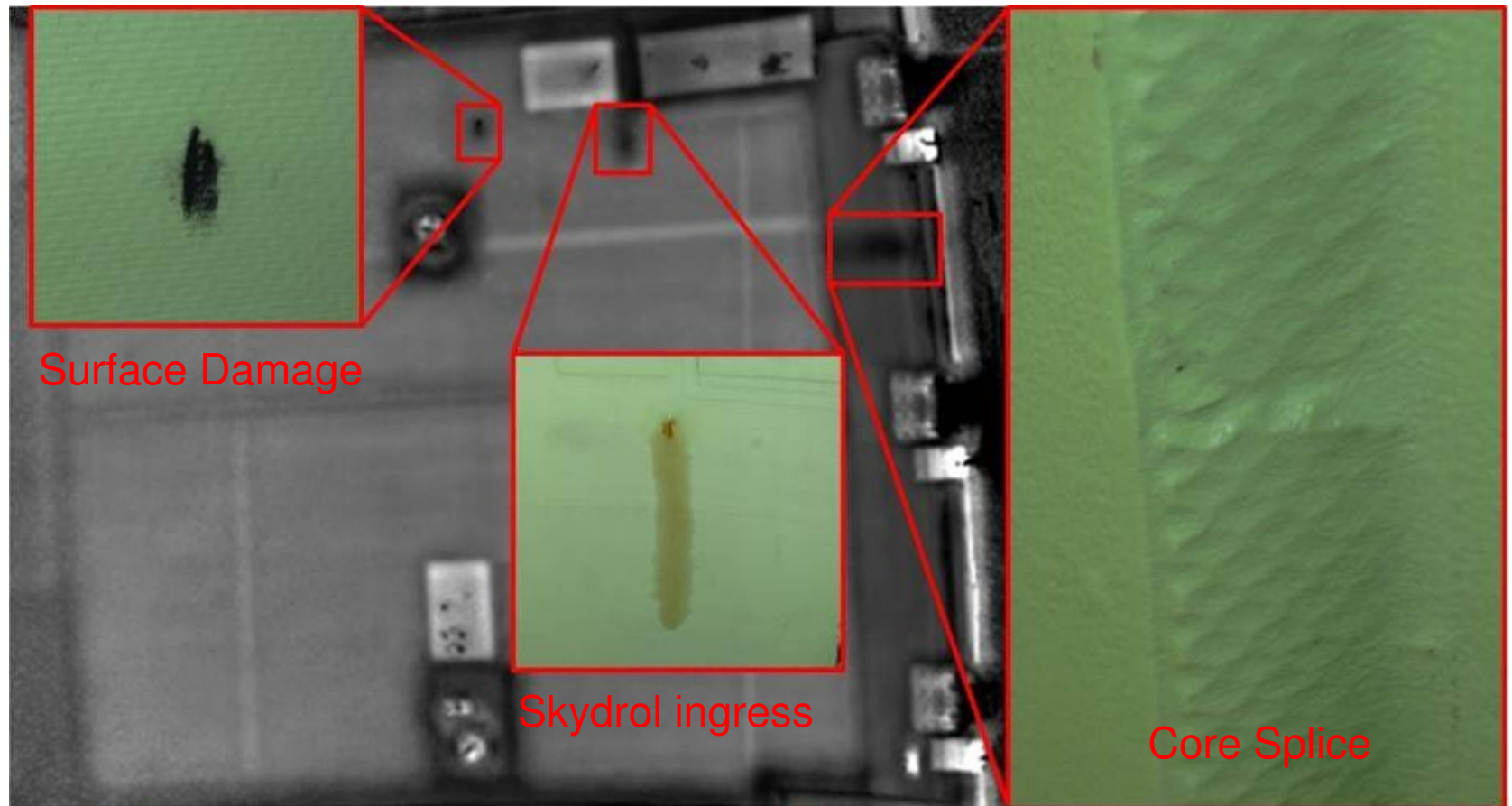


Sometimes indications are easy to identify....

Damage of Composite Structures

Inspection and Detection

....and sometimes not. What do I see here, and is it a problem ?

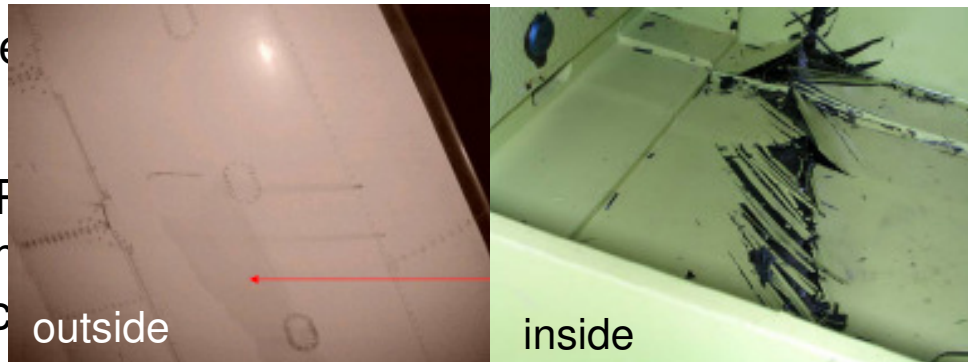


Damage of Composite Structures

Inspection and Detection

Composite Challenges

- Special knowledge, experience and training required – not a standard in the industry yet
- Damage can be hard to detect or even invisible (BVID, BVOD, NVD)
- Damage effects
- For CFRP problems blame of
- Loaded similar (changed by preloading)



A330 Vertical Stabilizer

Es ist schnell passiert ...

Hoppla, kurz mal nicht aufgepasst, schon wird's teuer. Ärgerlich bei Ihrem Auto. Fatal bei einem Flugzeug.

Besser: Aufpassen! M Lufthansa

Damage of Composite Structures

Types of Damage



Ground Service Vehicle



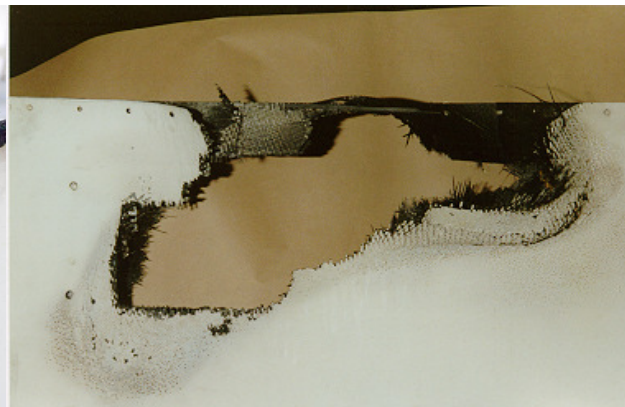
Bird Strike



Hail Strike



Lightning Strike



Overheat



Runway Debris

Damage of Composite Structures

Frequency and Economic Impact

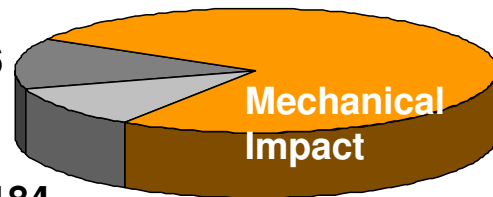
Fleet Damages 2006

Lightning Strike

216

Bird Strike

184



1248

Mechanical Impact

Fleet Size:

243 A/C (99WB, 144NB)

Events :

1647

Repair Cost:

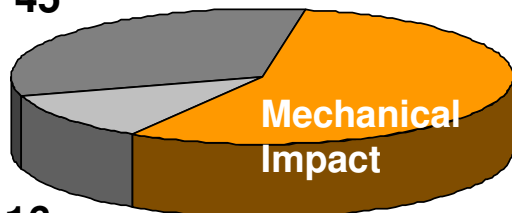
33 Mio €

Lightning Strike

45

Bird Strike

16



Events : 138

Fuselage

63

Widebody

Narrowbody

76

Frequency NB:

every 4600 flights

Frequency WB:

every 1000 flights



Damage of Composite Structures

Paint cracking

Typical damage



“Mud cracking”
appearance after 3 to 4
years service exposure on
inlet cowl outer barrel

**Not as spectacular as
a mechanical impact
damage, but the
customer (passenger)
sees it !**

⇒ Reputation ?

Damage of Composite Structures

Paint cracking

Typical damage



Another example of “mud cracking” appearance on a fan reverser sleeve.



Damage of Composite Structures

Paint cracking

Typical damage

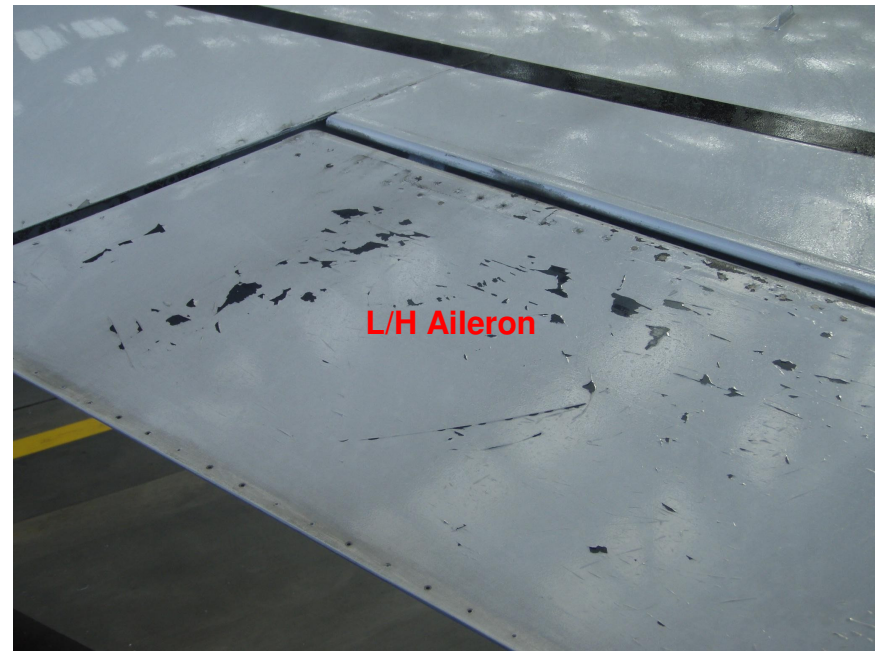


Comparison of paint performance on aluminum (left, paint in acceptable condition) and composite (right, paint cracked) substrate of a fan reverser sleeve

Damage of Composite Structures

Paint cracking

Typical damage



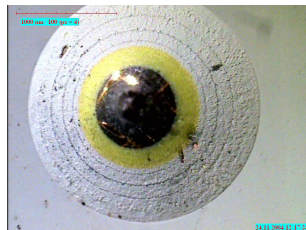
Damage of Composite Structures

Paint cracking

Painted Composite Structures suffer from paint cracking and chipping after few years of in flight service.

The root cause for this damage has not yet fully been determined. Possible causes are:

- Excessive paint system thickness



**Total:
629 μm**



**Total:
296 μm**

- Brittle filler compound used in excessive thickness
- Thermal stress between paint system and composite substrate
- Paint systems suitable for metals, but not for composites (?)
- Chemical degradation of the paint by influence of non fully reacted composite matrix resin constituents (?)

Damage of Composite Structures

Paint cracking

LHT Investigation Programs

To identify the original cause for paint cracking on composite structures, several investigation programs have been started:

- Monitoring of paint thickness on several components of new delivered aircraft
- Influence of individual process steps/parameters on paint behavior (cleaning, sanding, pore filler etc.)
- Evaluation of a flexible primer
- Sampling program with test specimens build up with unreacted epoxy hardener

Damage of Composite Structures

Paint cracking

Flexible Primer

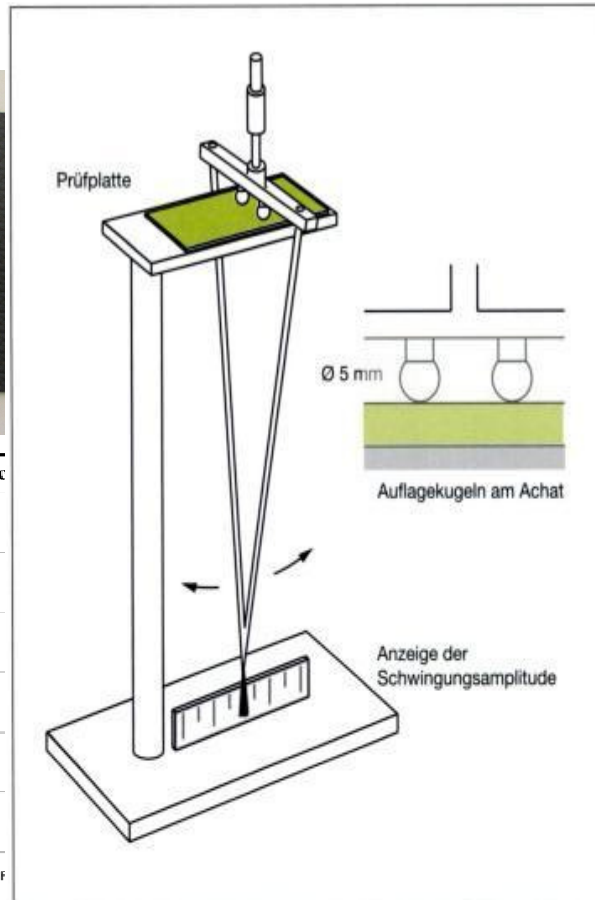
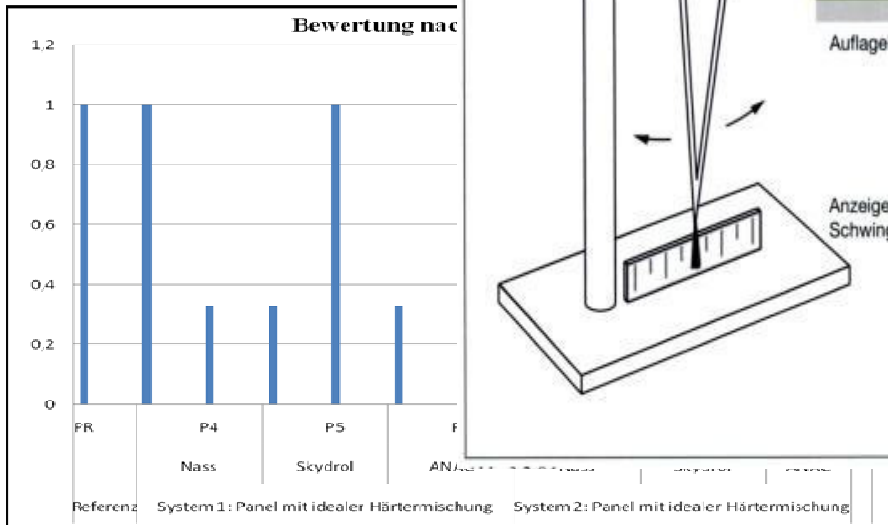
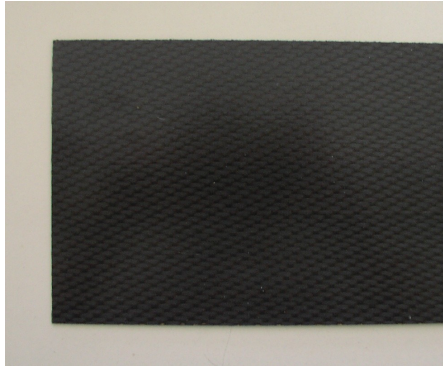


Chamber flaps painted with and without flexible primer after 18 month operation

Results showed significant influence of primer

Damage of Composite Structures

Paint cracking



Test panels using dry carbon fiber cloth and wet lay-up resin EA9396 have been manufactured. To determine the possible influence of unreacted resin hardener, three types have been made:

- with exact resin / hardener ratio
- with 10% more hardener
- with 20% more hardener.

Paint hardness was evaluated using the pendulum hardness test

Results showed no significant influence of unreacted resin hardener

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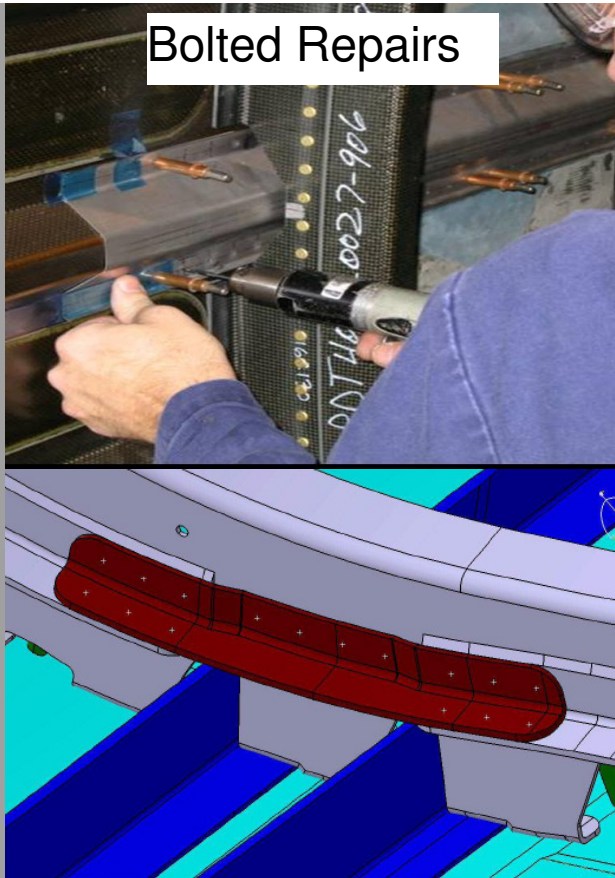
Repair of Composite Parts

Composite Repair Examples

Repair of Composite Parts

Types of Repair

Bolted Repairs



- Titanium or CFPR Doubler

Bonded Repairs



- Speedtape (temporary „return home“)
- Resin Sealing (temporary)
- Pre-cured or Co-Cured CFPR Doubler
- Wet lay up (Room- or elevated temperature)
- Pre-Preg Repairs, Structure build-up

Repair of Composite Parts

Types of Repair

Bolted Repairs

- Drilling and bolting of laminates overcome problems with CFRP surface contaminations
- Additional mechanical bearing stresses are implied
- Longitudinal carbon fibres are destroyed
- Doublers might not be readily available if Ti or CFPR
- Only repair method qualified for primary structure right now

Bonded Repairs

- Feasibility for primary structure is currently heavily debated
- Primary reason is uncertainty of adhesive strength and long term performance
- Surface contamination is a major concern
- For secure bonded repair procedures contaminants have to be properly analysed; qualitatively as well as quantitatively

Repair of Composite Parts

Composite Challenges

Composite Challenges

- Specialized personnel
- Quality control and process control
- Quality control and process control
- Special equipment and tooling necessary
- State of the art **„Trust adhesively bonded repairs, which are riveted!“ (J. Rouchon, EASA)**
- Large quantities of material – expensive
- Limited and/or untimely availability of material. Minimum purchase amounts in combination with shelf life

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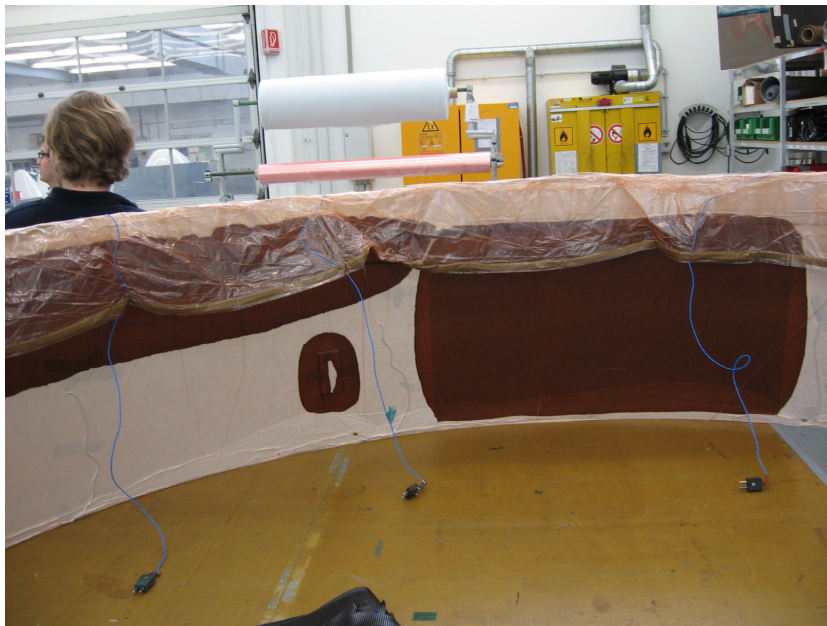
Composite Repair Example

Bonded - Thrust Reverser Translating Cowl „Shark Bite“



- CF6-80 Thrust Reverser Translating Cowl
- Sandwich Panel made of Honeycomb + CFPF Skins
- Damage caused by blocker door release

Composite Repair Example Bonded - Thrust Reverser Translating Cowl „Shark Bite“

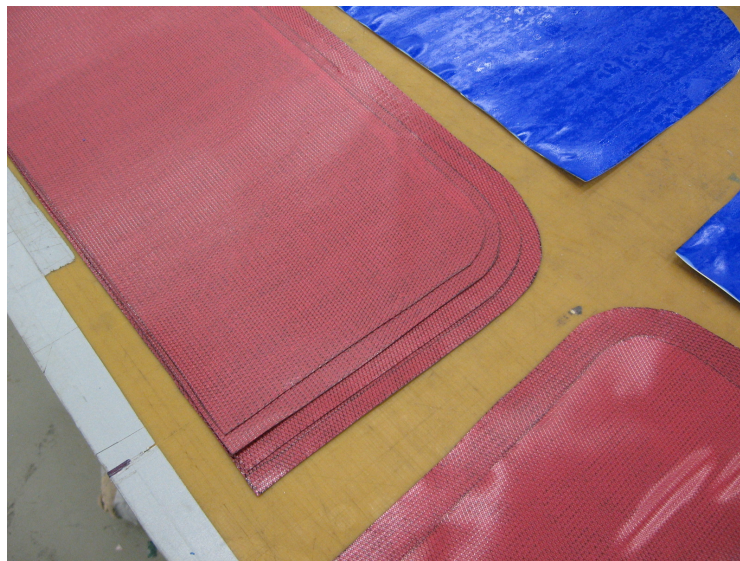


Manufacturing of Precured Fillers and Traveling Test Coupon (ILS Test) reproducing original material & ply lay up

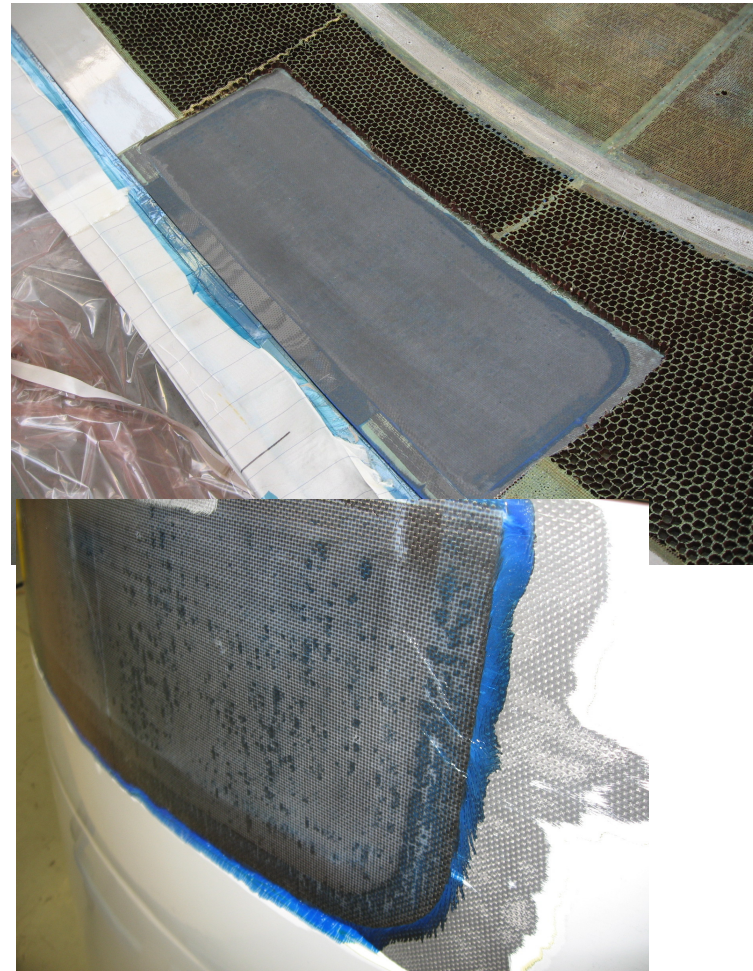


Fillers & Coupons after autoclave curing and reworking

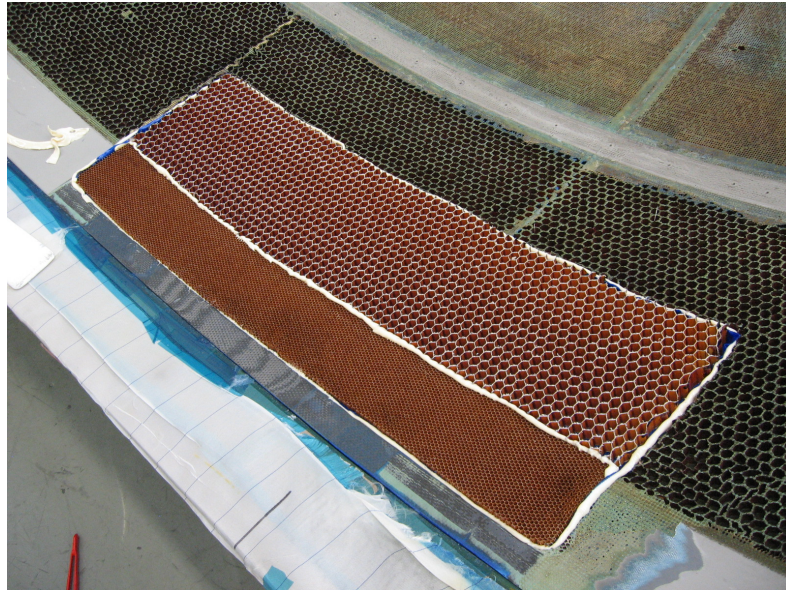
Repair of Composite Parts Thrust Reverser Translating Cowl „Shark Bite“



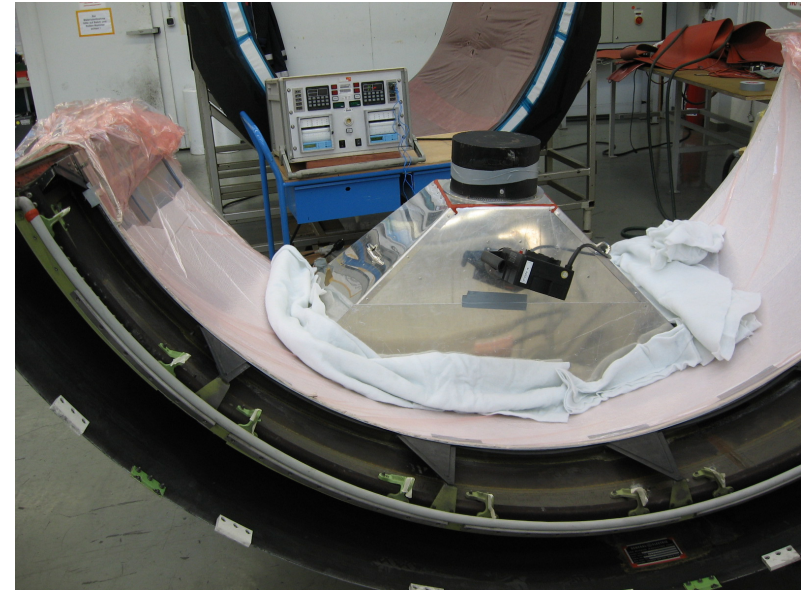
**Bonding the filler to the
translating cowl**



Repair of Composite Parts Thrust Reverser Translating Cowl „Shark Bite“



New Honeycomb is applied

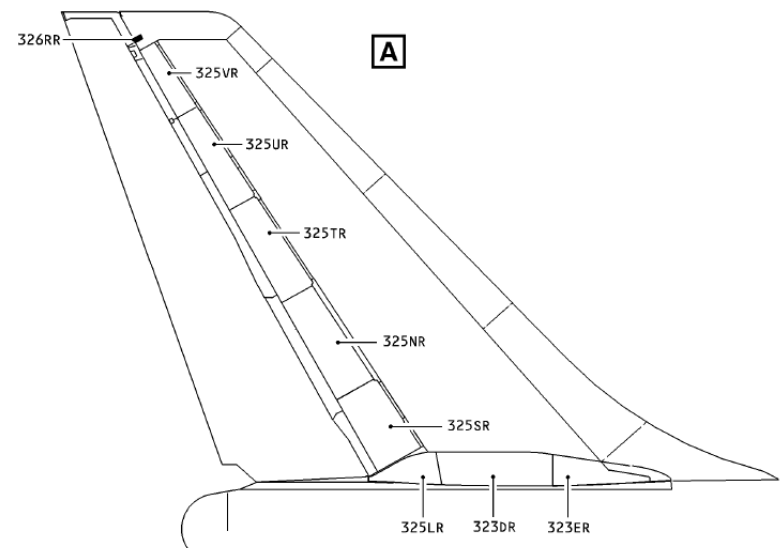
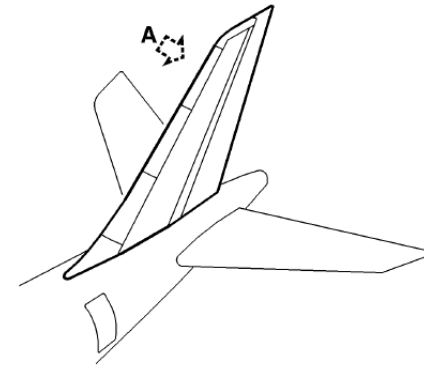


Local Bonding of the Assembly

Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

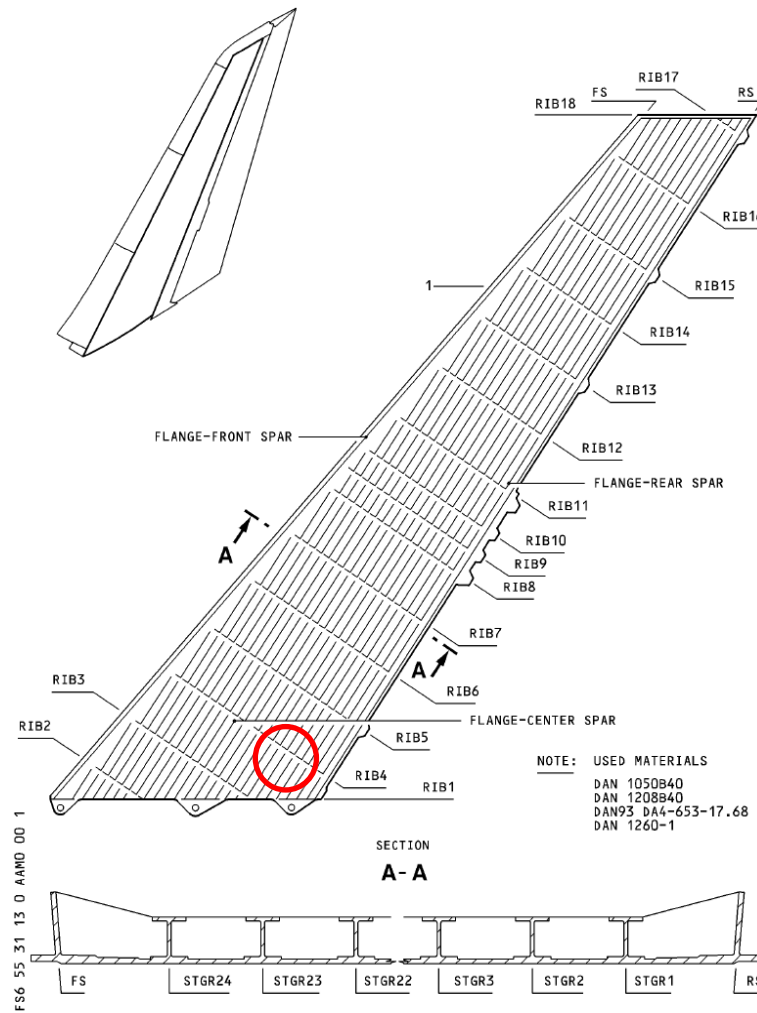
- During D-Check of an Airbus A340, a damaged stringer in the Vertical Stabilizer has been found during re-installation of the fairing between fuselage and the VS
- The damage was a disbonded stringer flange in the region of a fastener used for the fairing attachment
- Reason for damage unclear



Composite Repair Example

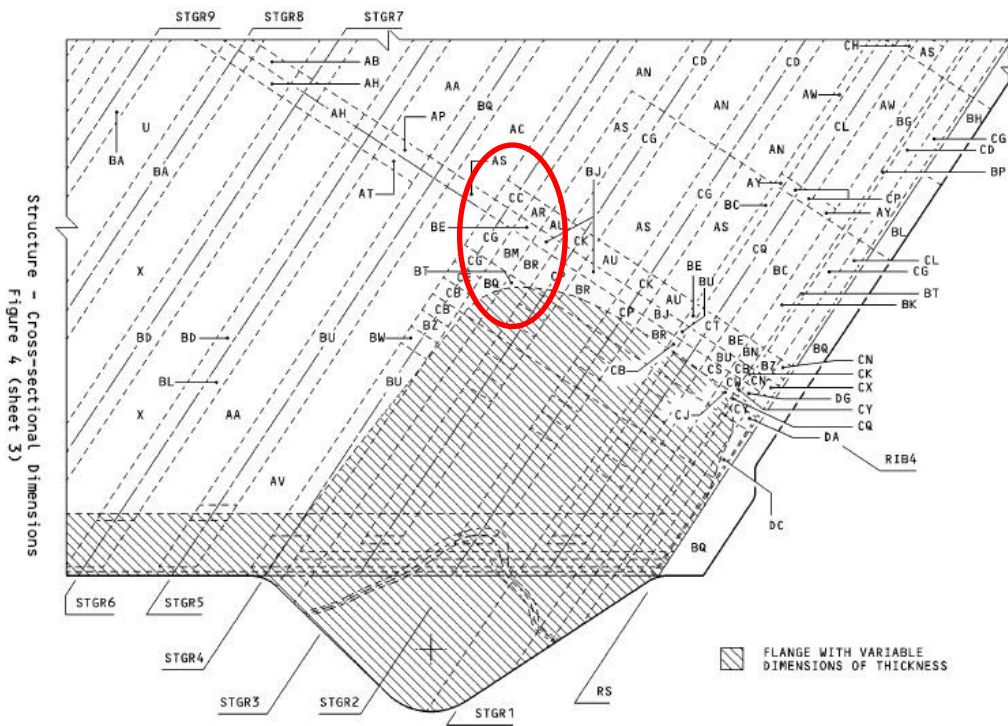
Bolted – Vertical Stabilizer Stringer Delamination

Affected area



Composite Repair Example Bolted – Vertical Stabilizer Stringer Delamination

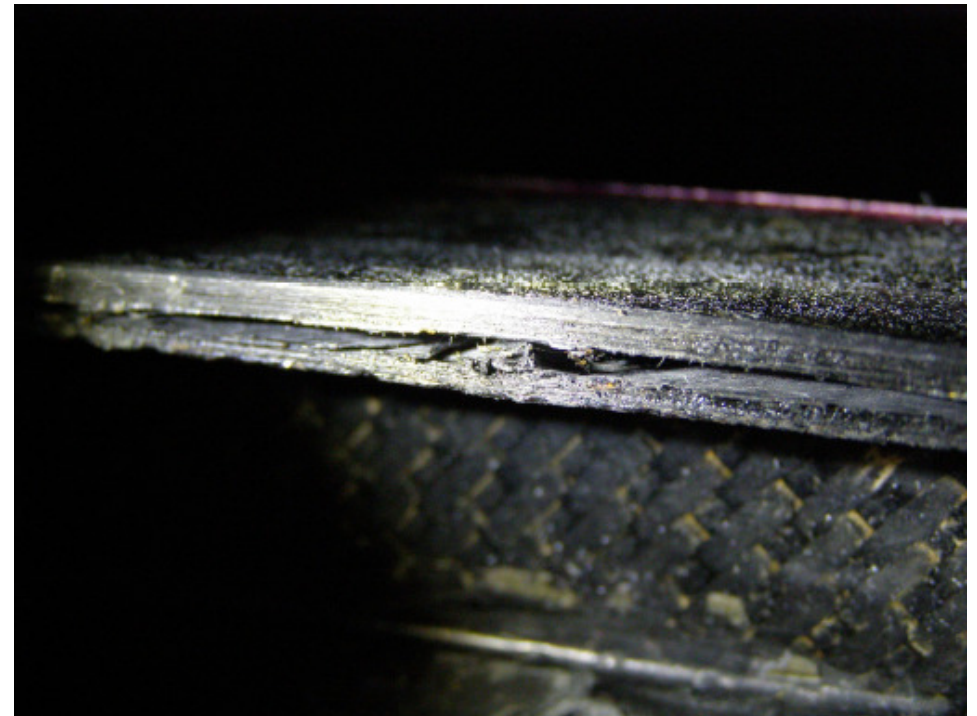
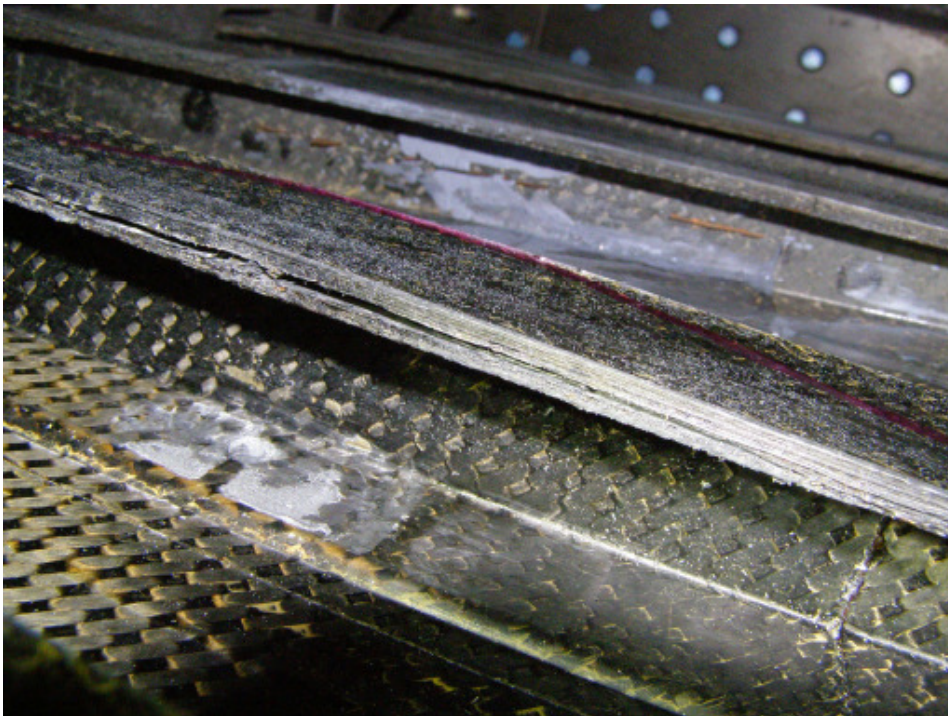
Affected area



Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

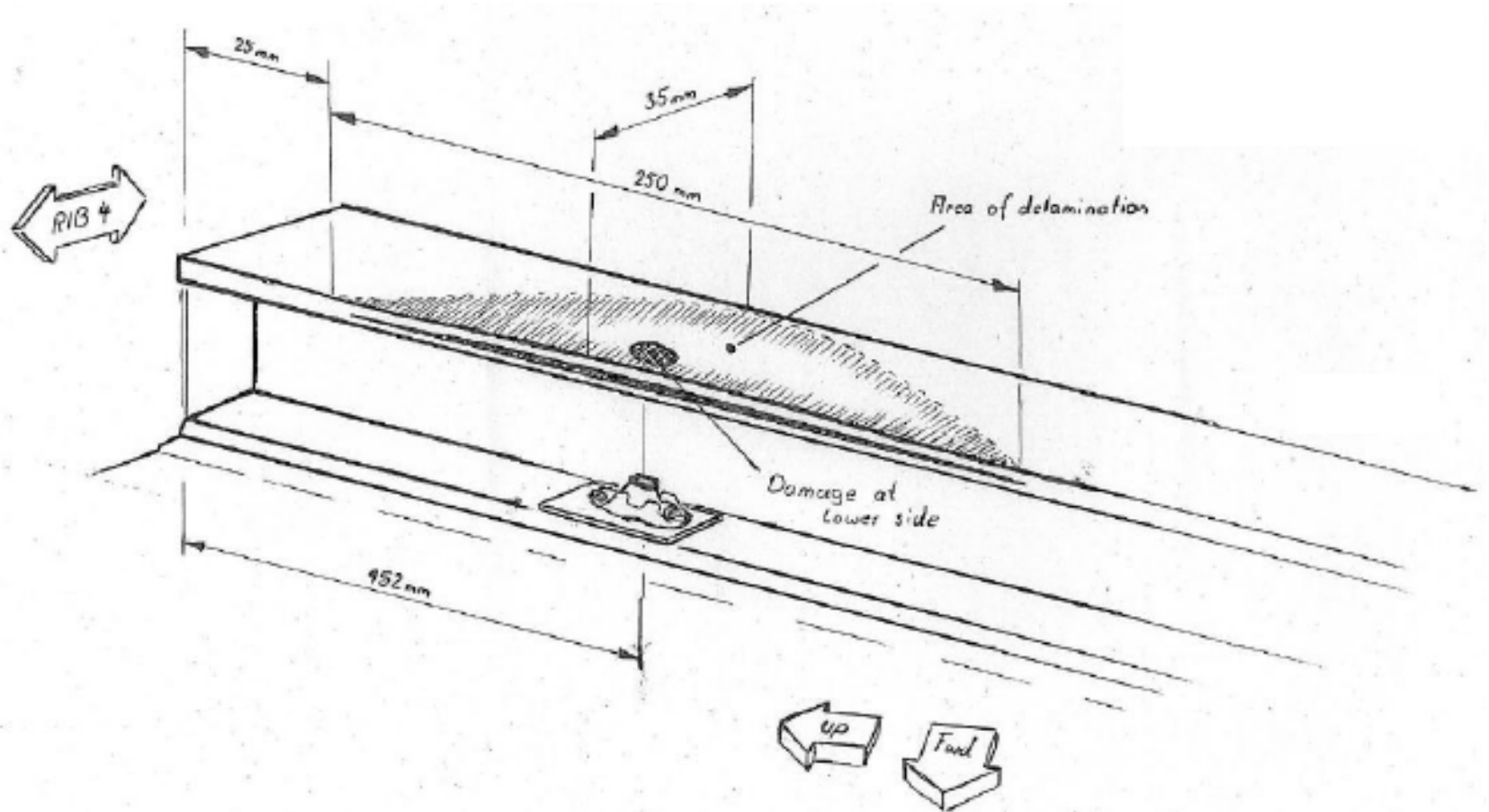
Affected area



Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

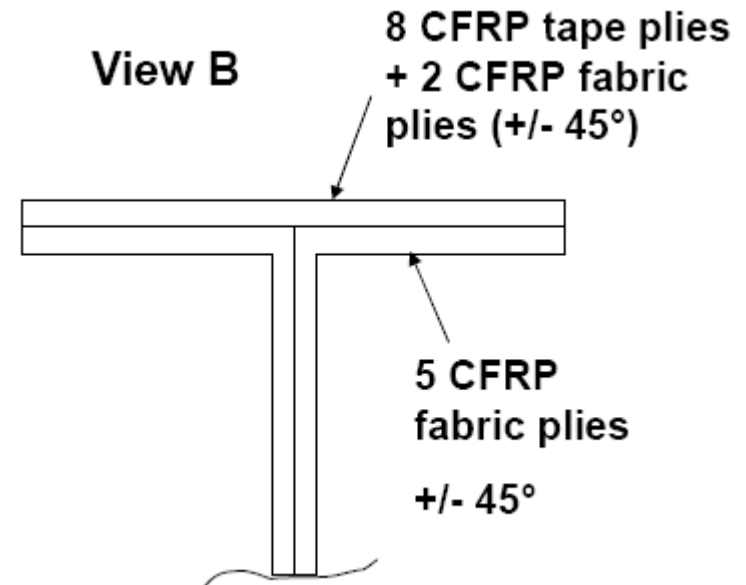
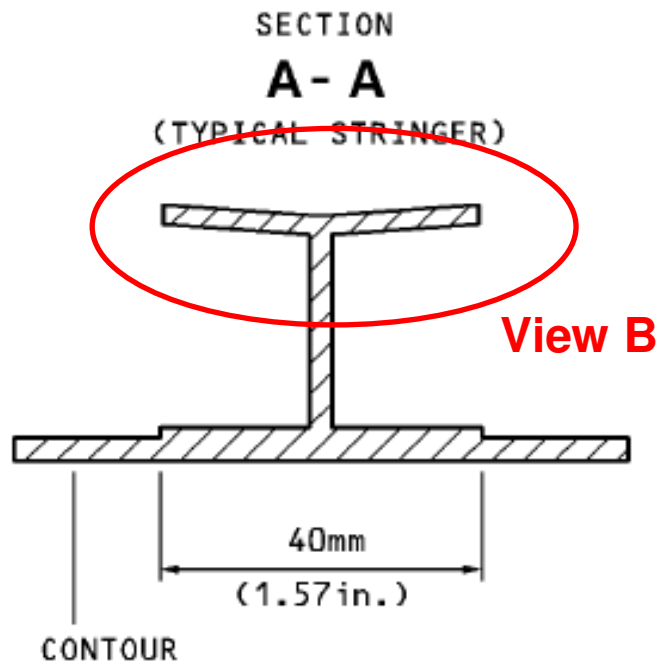
Extend of damage



Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

Design of damaged structure



Question: Tape layers affected ?

no

yes

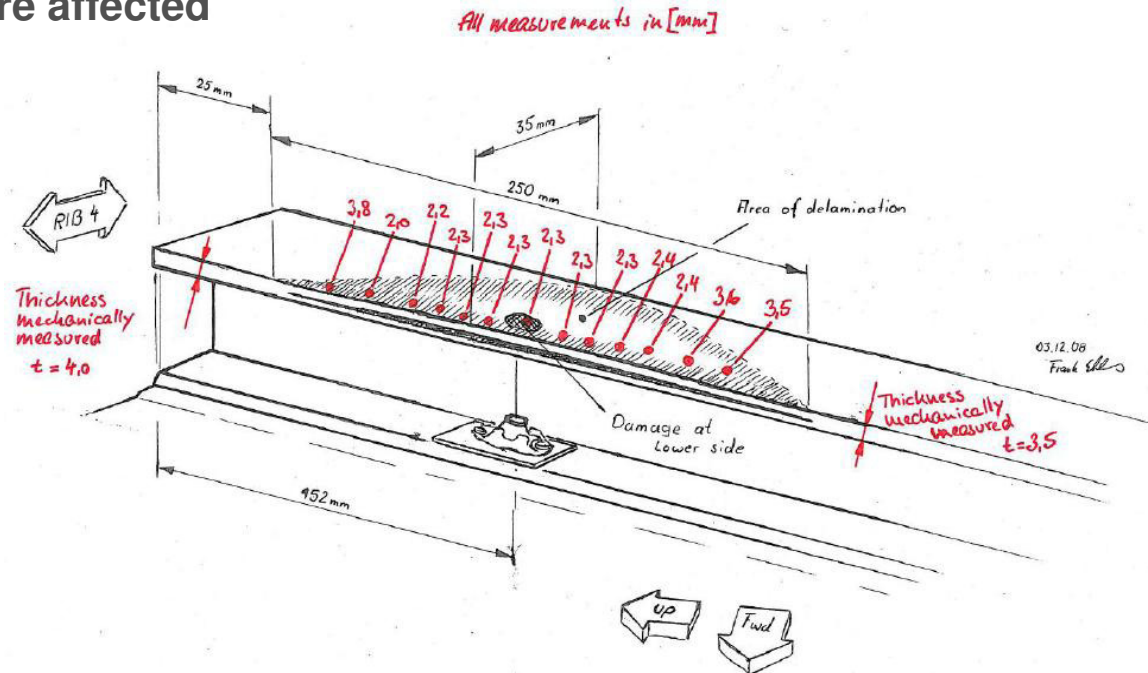
Repair can end before rib 4 („small repair“)

Repair must involve Rib 4 („large repair“)

Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

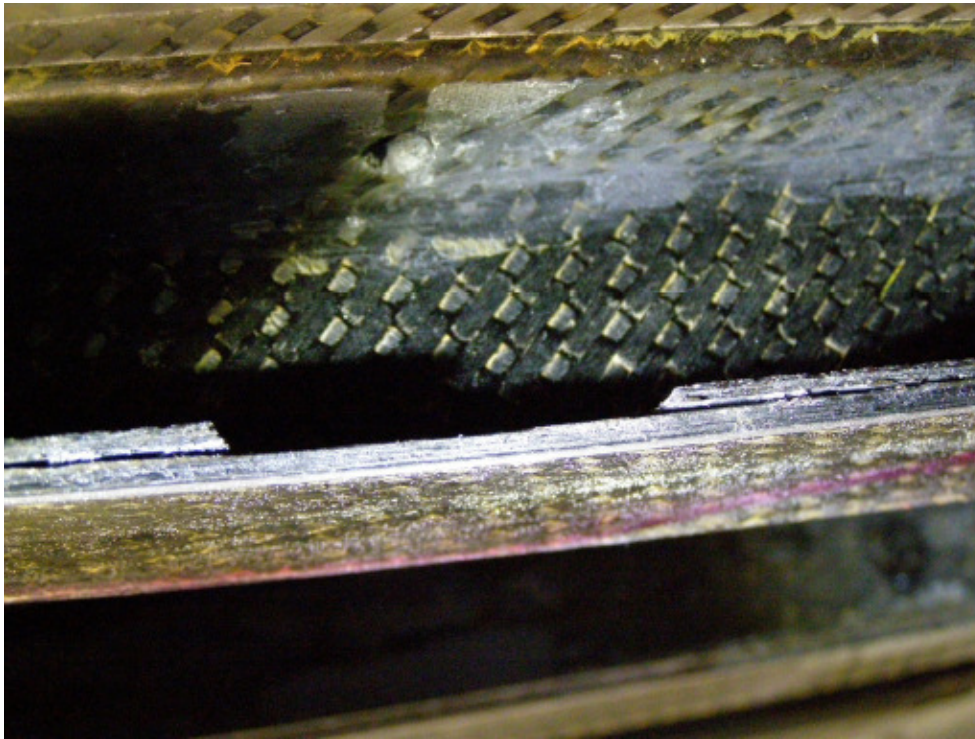
- In order to determine depth of the damage, an ultrasonic inspection of the flange was performed
- The measured values could not be definitely associated with expected CFRP layer thickness
- It was decided to mechanically remove the damage to clarify whether the tape layers were affected



Composite Repair Example

Bolted – Vertical Stabilizer Stringer Delamination

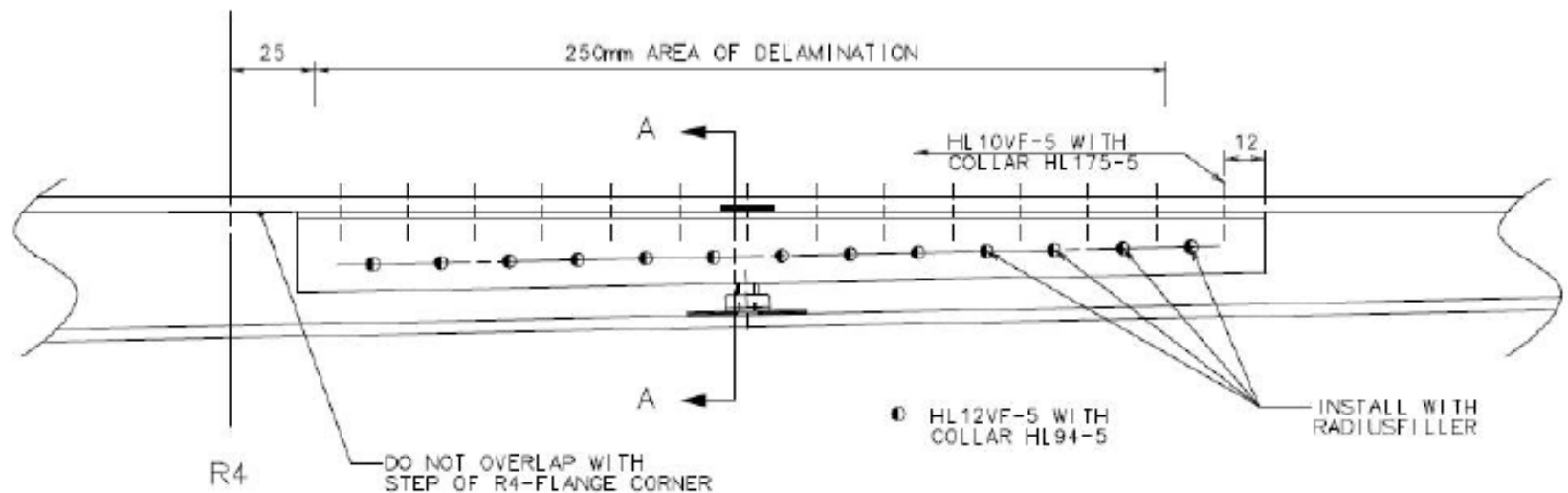
Damage removed



Composite Repair Example

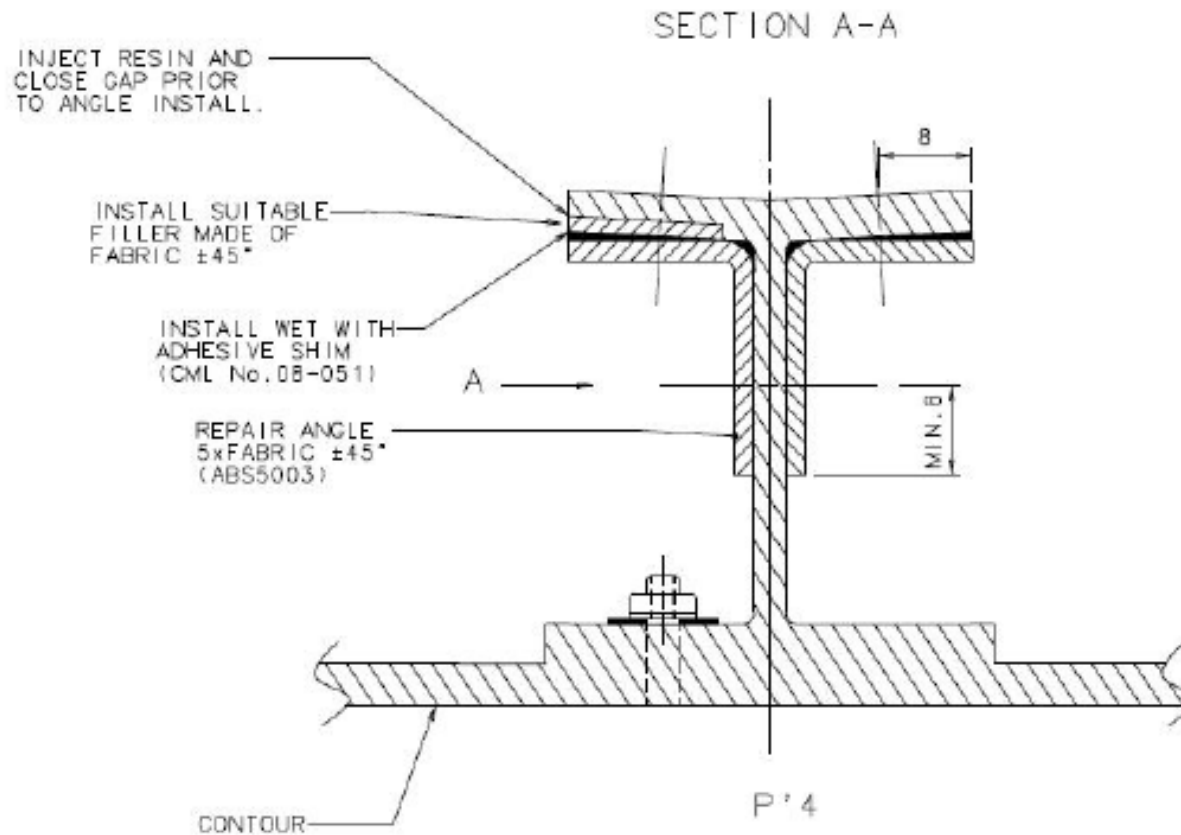
Bolted – Vertical Stabilizer Stringer Delamination

- Tape layers not affected \Rightarrow “small repair” to be performed
- Repair solution is installation of pre-cured angles (bolted)
- Repair classified minor and permanent, no re-inspection



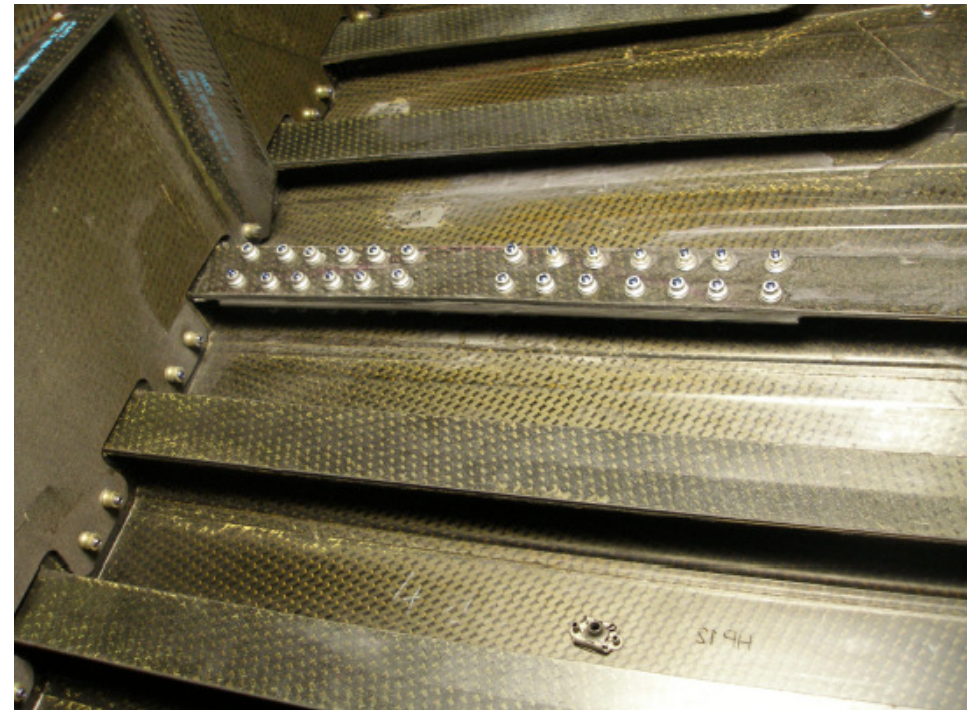
Composite Repair Example

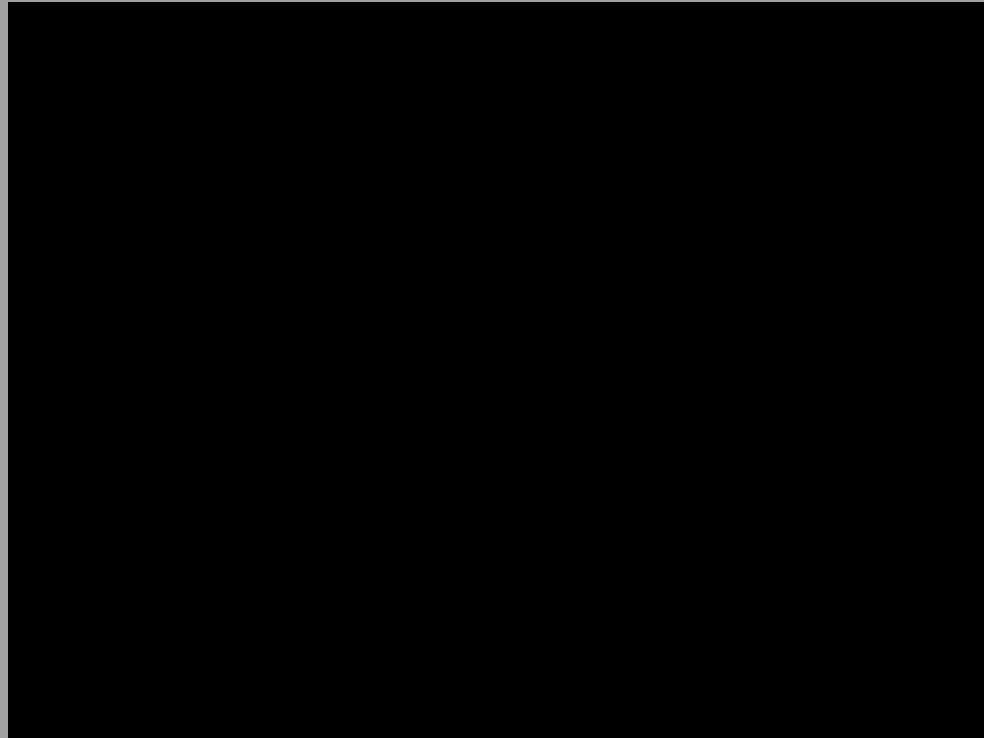
Bolted – Vertical Stabilizer Stringer Delamination



Composite Repair Example Bolted – Vertical Stabilizer Stringer Delamination

Completed Repair





Thank you for your attention

...and enjoy your flight with Lufthansa