Presented by

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Rudder structural investigations

Relevant to rudders CFRP rudder PN A55471500 series

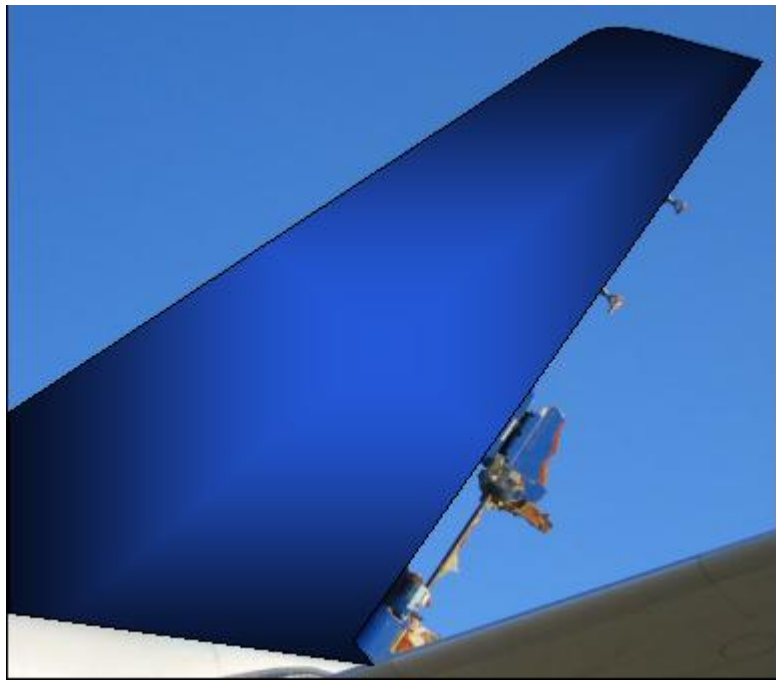
Content

- Rudder structural failure in flight
- Rudder disbond detected during maintenance
- Inspection of Z-profile design rudder series
- Conclusion

Rudder structural failure in flight

Event sequence

- March 2005
- Normal flight until the aircraft reached FL350
- Sudden vibrations and loud noise
- The aircraft entered a Dutch roll that decreased and eventually ceased when descending
- On ground, major part of the rudder had departed the aircraft



Rudder structural failure in flight

Scenarios ruled out

- Not an operational event
  - Extract from NTSB advisory dated May 5, 2005

    Quote

    "Preliminary indications from the flight data show that the pilots were not manipulating the rudder"

    "This event is not similar to AA587 accident which probable cause was "the vertical stabilizer separated from the aircraft in flight after experiencing aerodynamic loads beyond the plane's design strength following the first officer's unnecessary and excessive rudder pedal inputs."

    "In the case of the flight 587 accident, the data indicate that the rudder remained intact and attached to the vertical fin until the fin separated from the airplane."

    Unquote

Rudder structural failure in flight

Scenarios ruled out

- Not an operational event
  - Rudder was not being manipulated
- Not a systems event
  - Systems operated as per design
    - No uncommanded rudder input
    - No deflection beyond theoretical values
- Not a FOD event
  - According to plots provided, rudder was not impacted by a foreign object immediately prior to separation

Rudder structural failure in flight

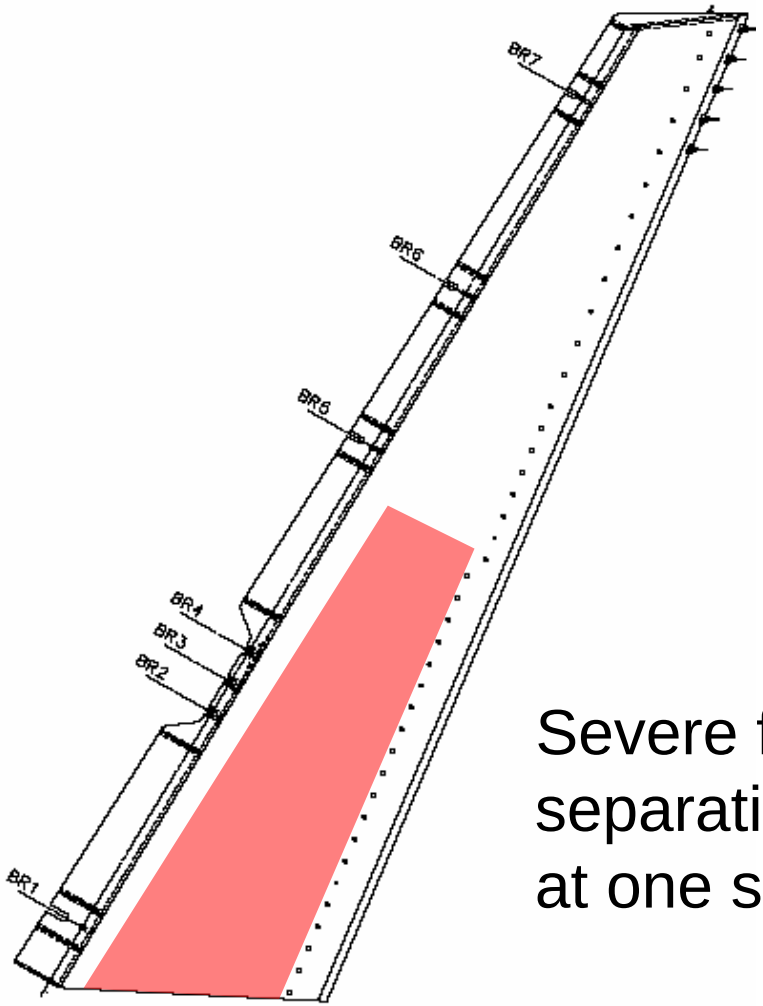
A dynamic phenomenon

- Flight data recordings evidenced a dynamic event prior to rudder separation
- It appeared to be a “flutter like” phenomenon

- However, **aircraft is flutter free**
- The rudder would not enter into flutter without a severe pre-damage condition

Rudder structural failure in flight

Most likely scenario



Severe face sheet separation from core at one side panel

Inspections launched further to event

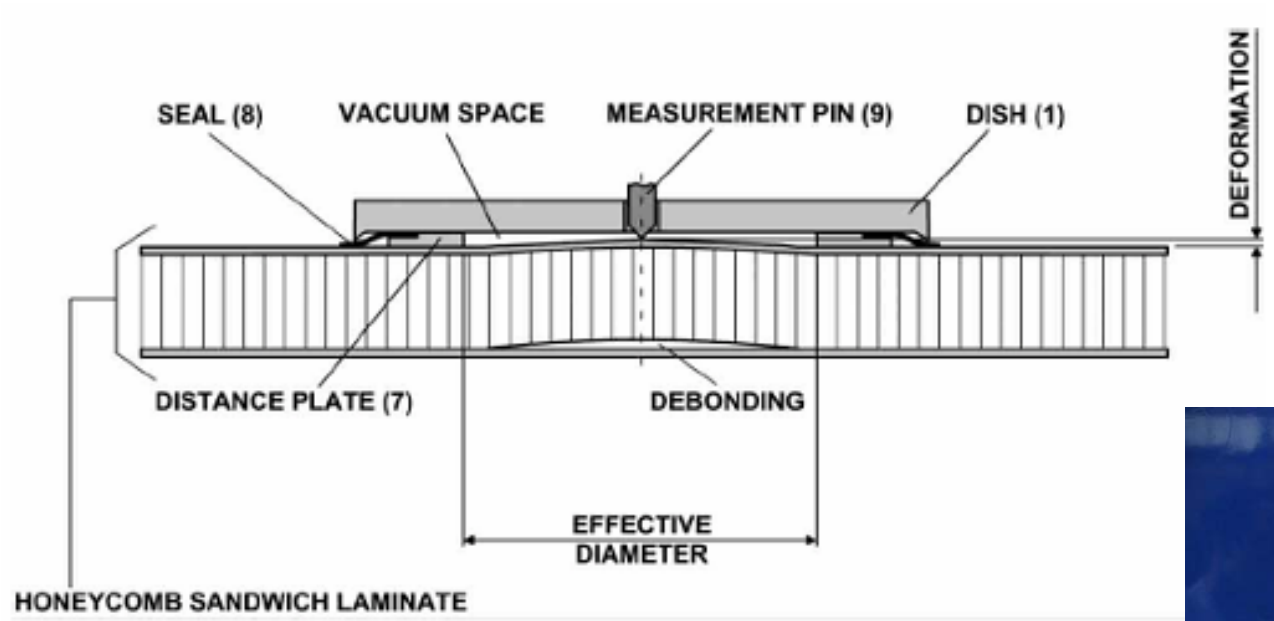
Tap test & ELCH

- In-service rudders have been inspected with a detailed visual inspection plus a tap testing
  - No damage approaching level identified as necessary to trigger flutter scenario by flutter studies

- Some A/C have been more deeply inspected using a vacuum based inspection method
  - Fleet leaders were included (75000FH, 35000FC approx)
  - All rudders found in good condition

ELCH principle

- The test units operates to the principle of deformation measurement of a sandwich structure under vacuum



Content

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- Rudder disbond detected during maintenance
- Inspection of Z-profile design rudder series
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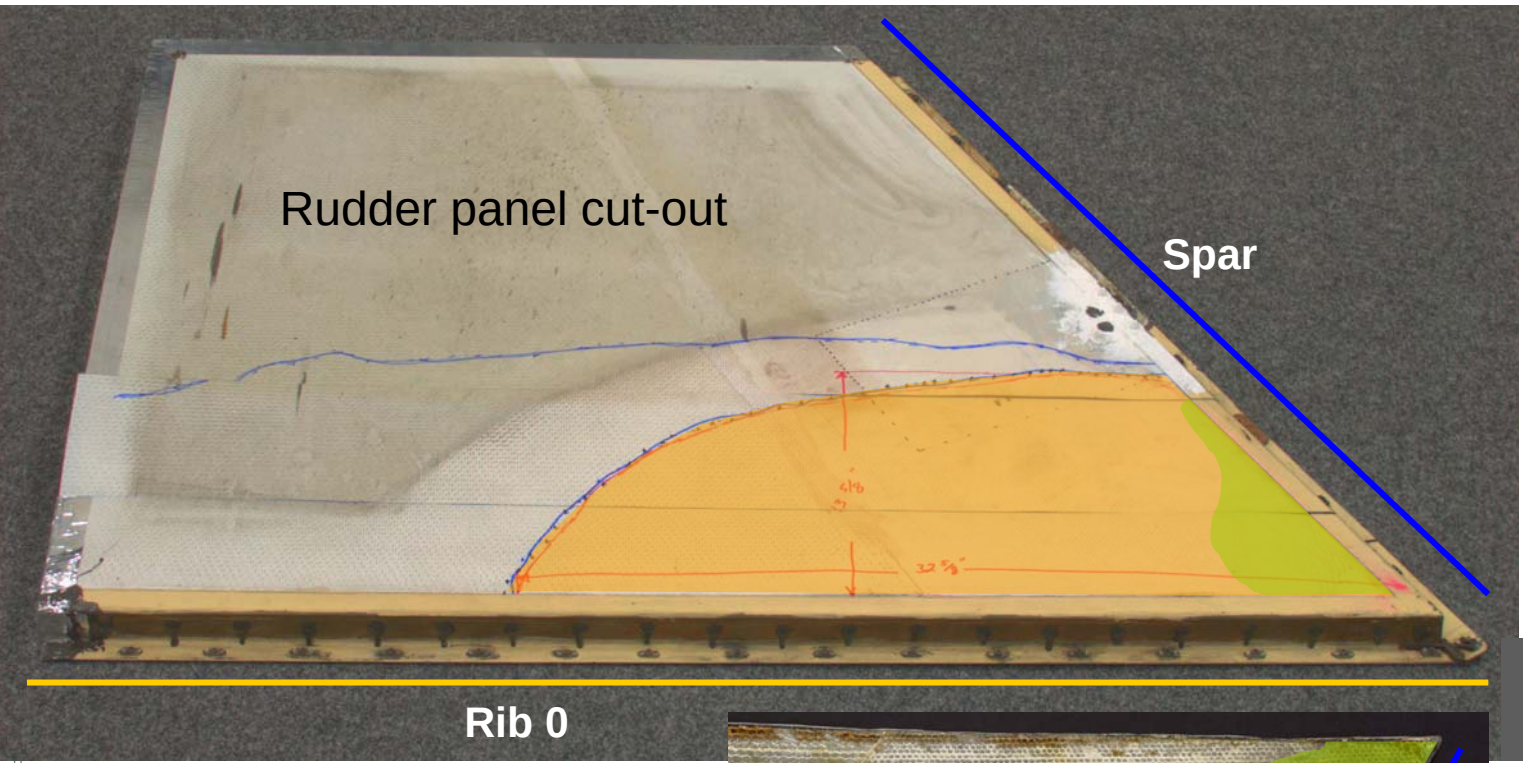
Rudder disbond

Occurrence

- December 2005
- Lower rib was removed for maintenance
- Inner skin to core disbond was detected

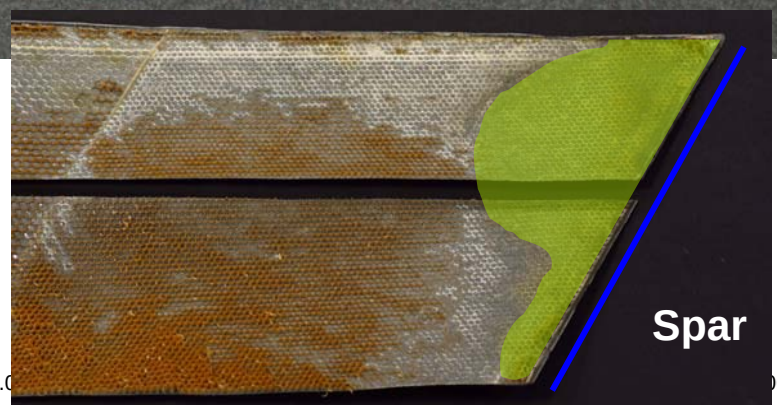
Rudder disbond

Hydraulic fluid contamination at inner face



Hydraulic fluid contamination

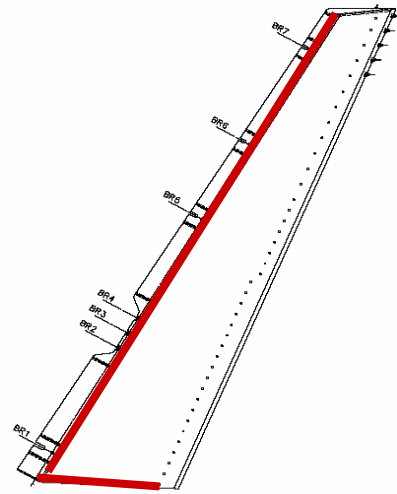
Inner skin flipped after removal

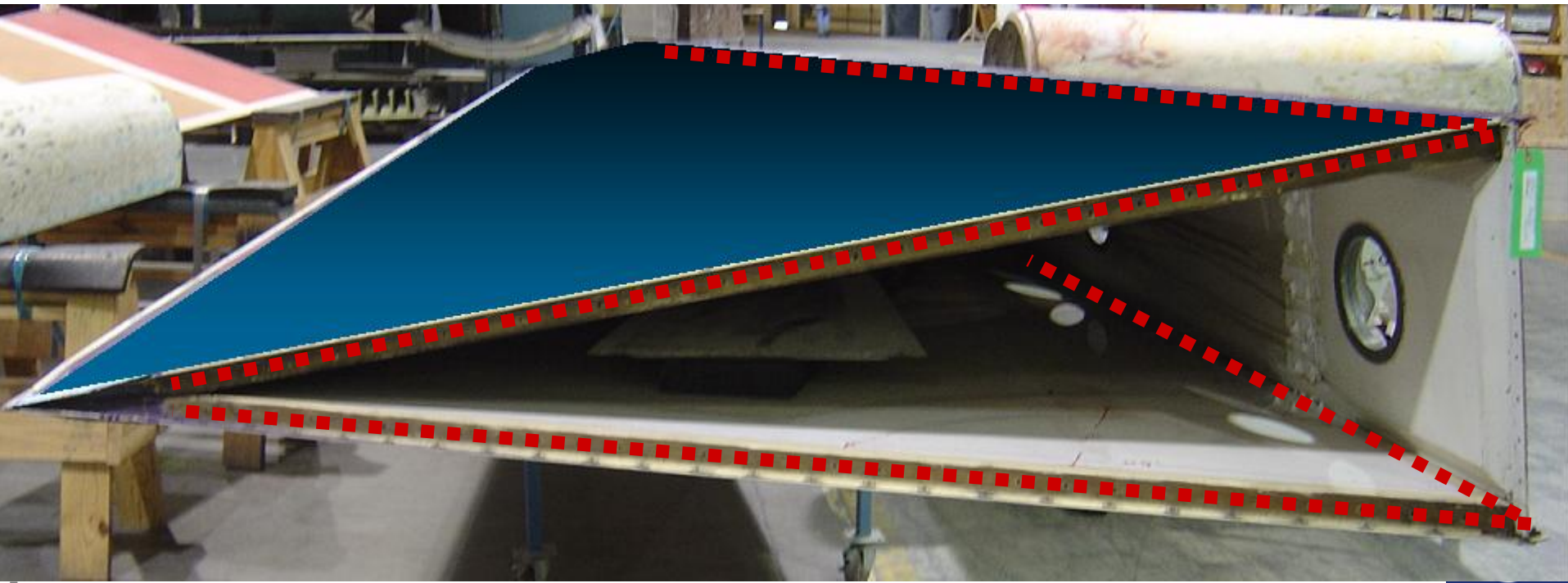


Rudder disbond

Fluid path specific to Z-profile design rudder series

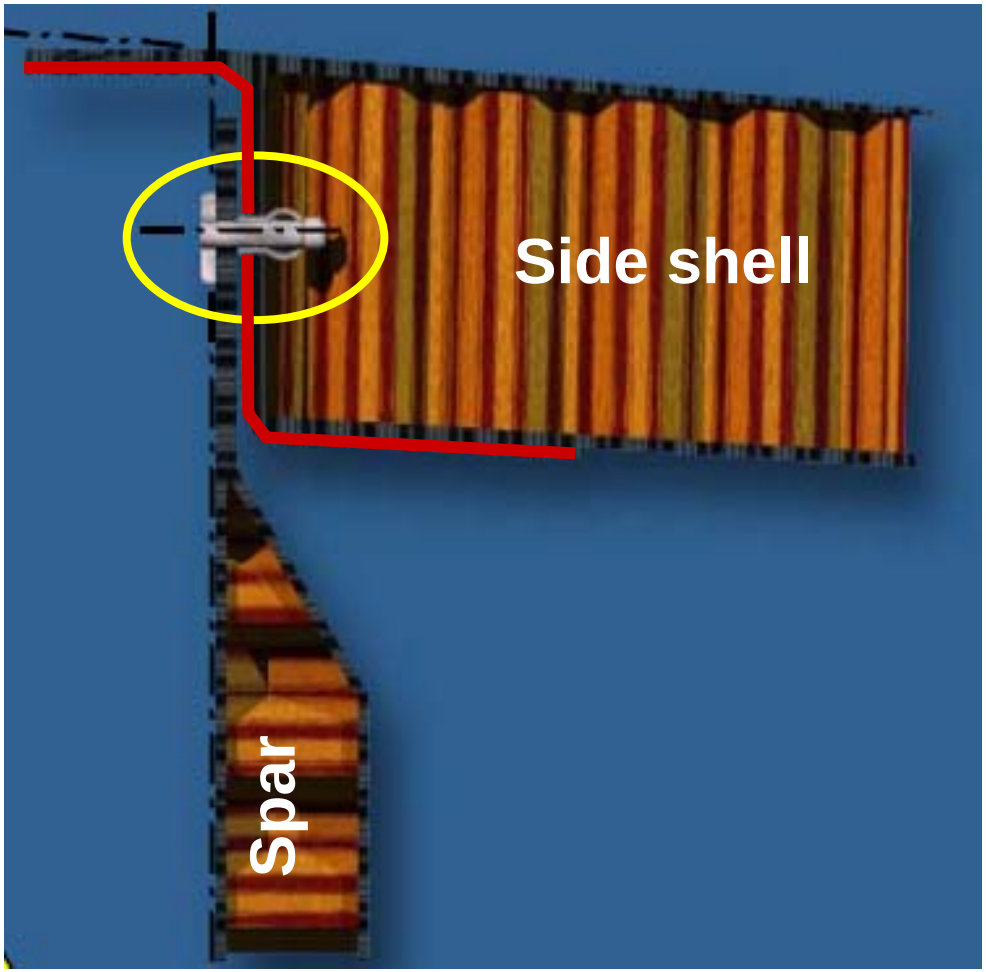
- Z-profile is fitted on panel edges
  - at connection to the spar
  - at connection to the rib 0





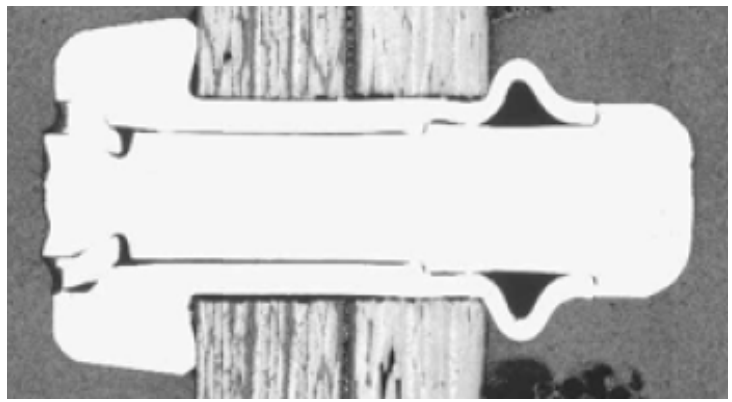
Rudder disbond

Fluid path specific to Z-profile design rudder series



- Blind rivets used for spar to shell connection
- Hydraulic fluid had penetrated past some rivets

Section cut of blind rivet



Rudder disbond

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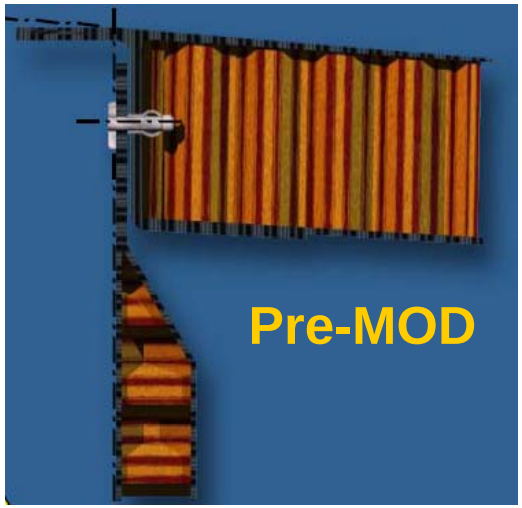
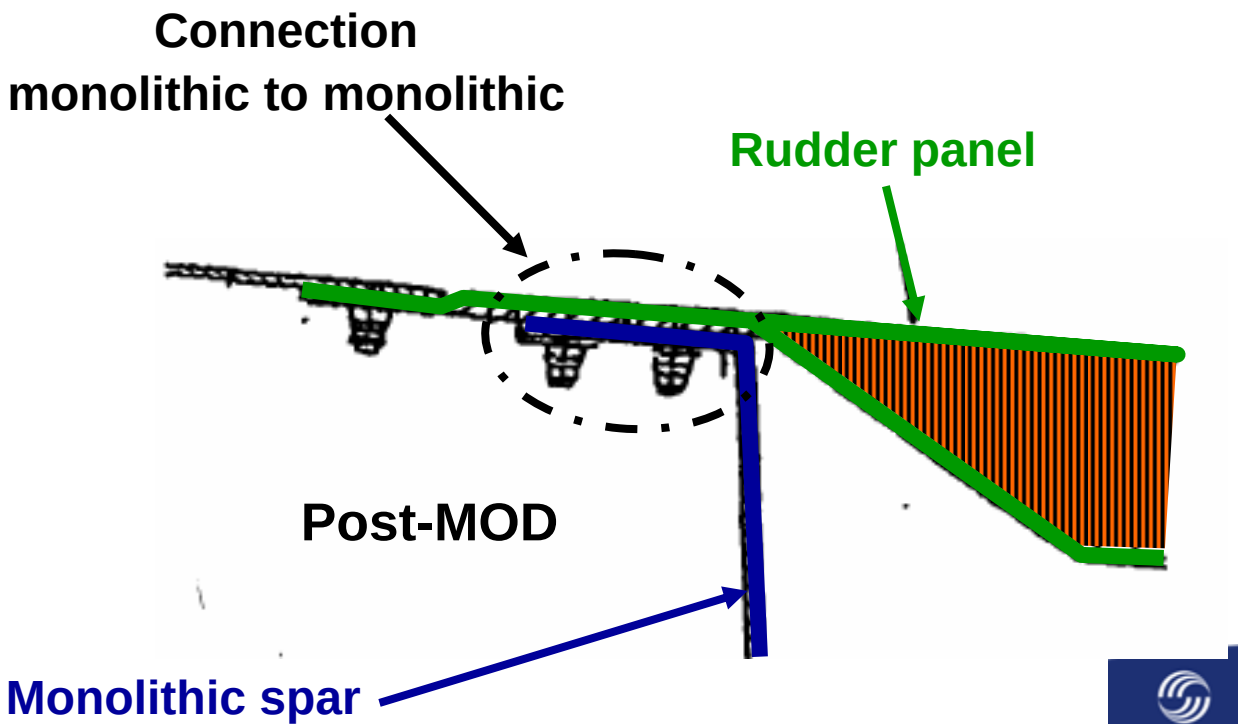


- Other design rudders are not affected



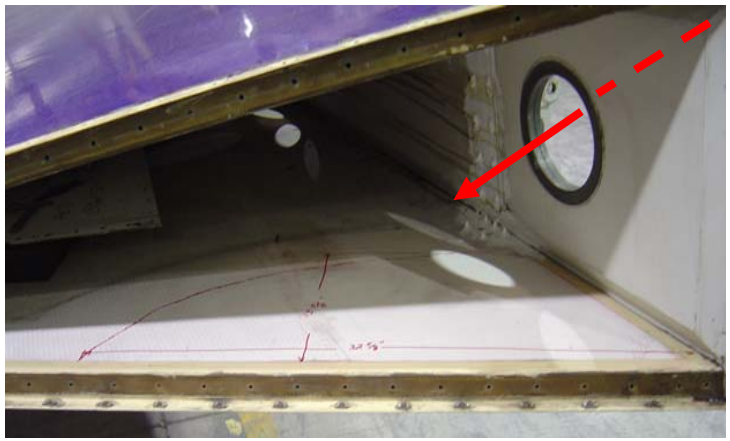
Rudder disbond

Time effect of hydraulic fluid contamination

- Airbus investigates how hydraulic fluid affects structural integrity over time
- Results have indicated that hydraulic fluid has less critical effect than expected
  - At disbonded area, disbond most likely occurred first and favored the contamination

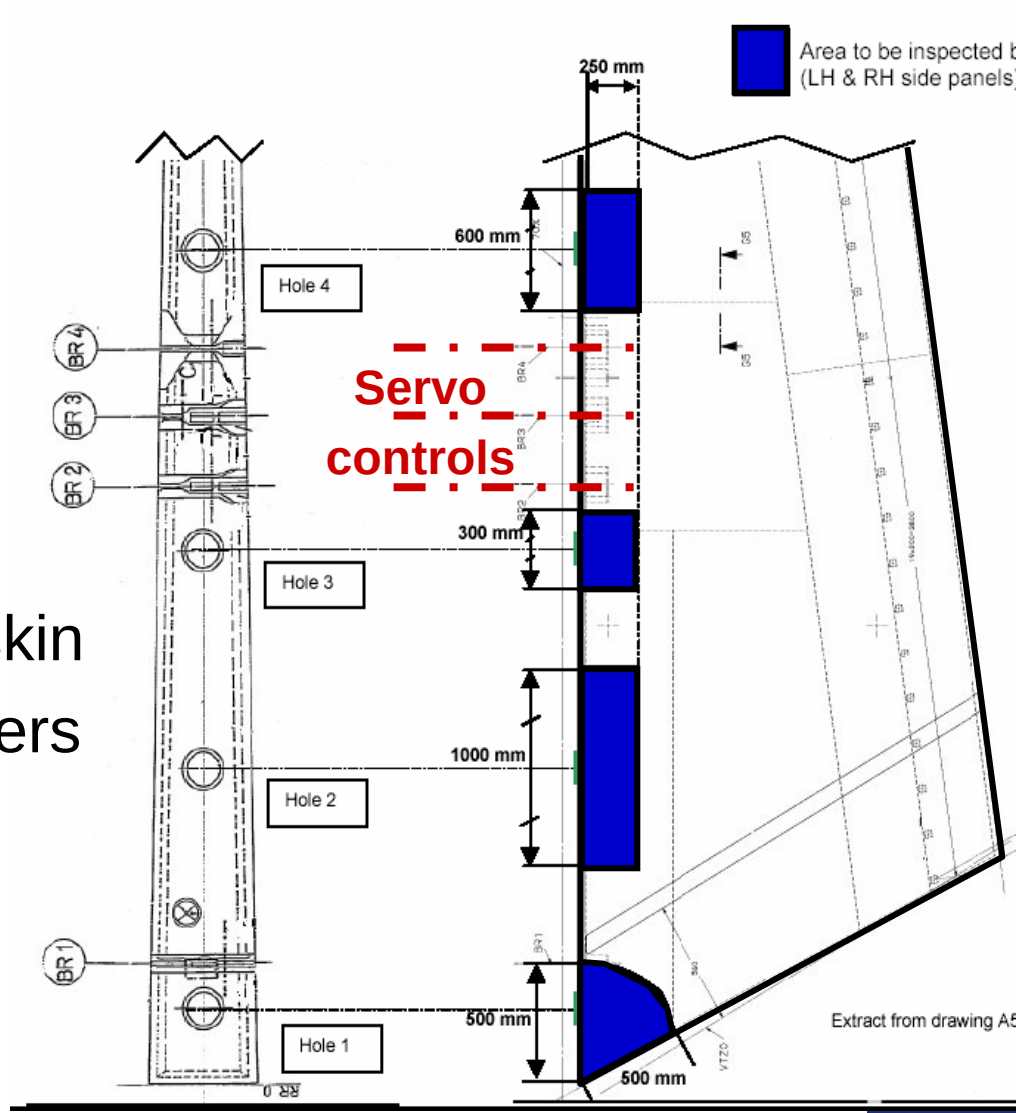
Inspections launched further to finding

Tap test & ELCH



- Tap test of accessible inner skin
- ELCH of some selected rudders

- All rudders found airworthy



Most likely scenario

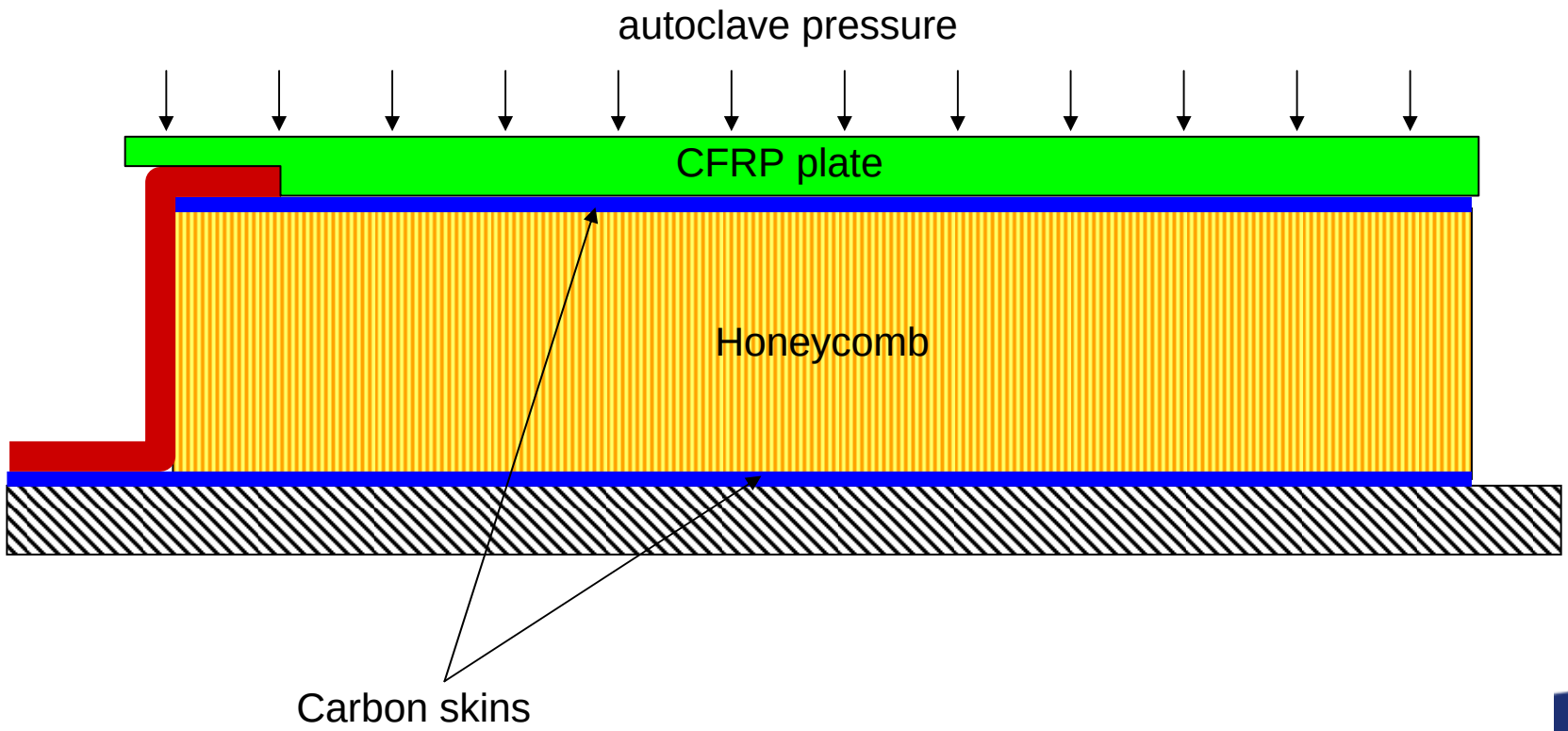
Disbond initiation behind the Z-profile

- During manufacturing, panels are cured with the Z-profile installed
- A CFRP plate covers the panel for application of pressure
- If pressure is not sufficient during curing, bond performance is affected
- With flight cycles, aerodynamic suction loading and in-plane compression, initial disbond may grow over FC

Most likely scenario

Pressure application during curing

- CFRP plate is designed to compensate for Z-profile thickness
  - No gap between plate and inner skin

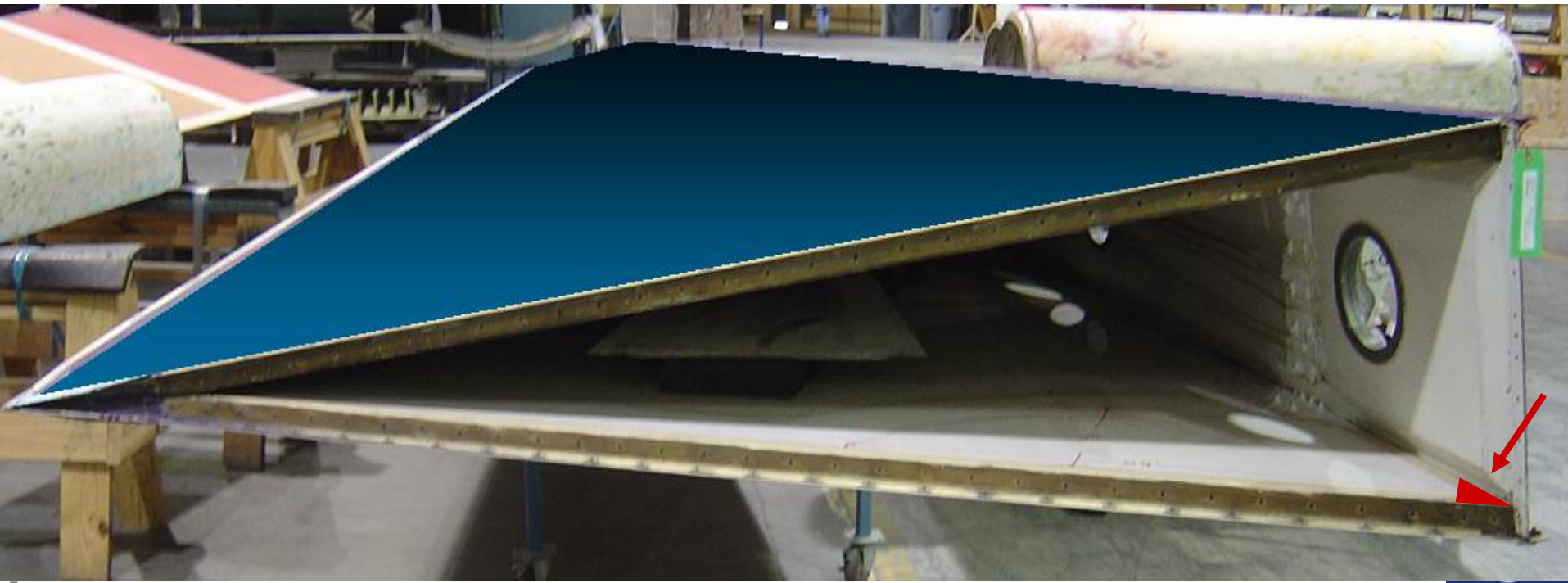


Most likely scenario

Possible lack of compensation during curing

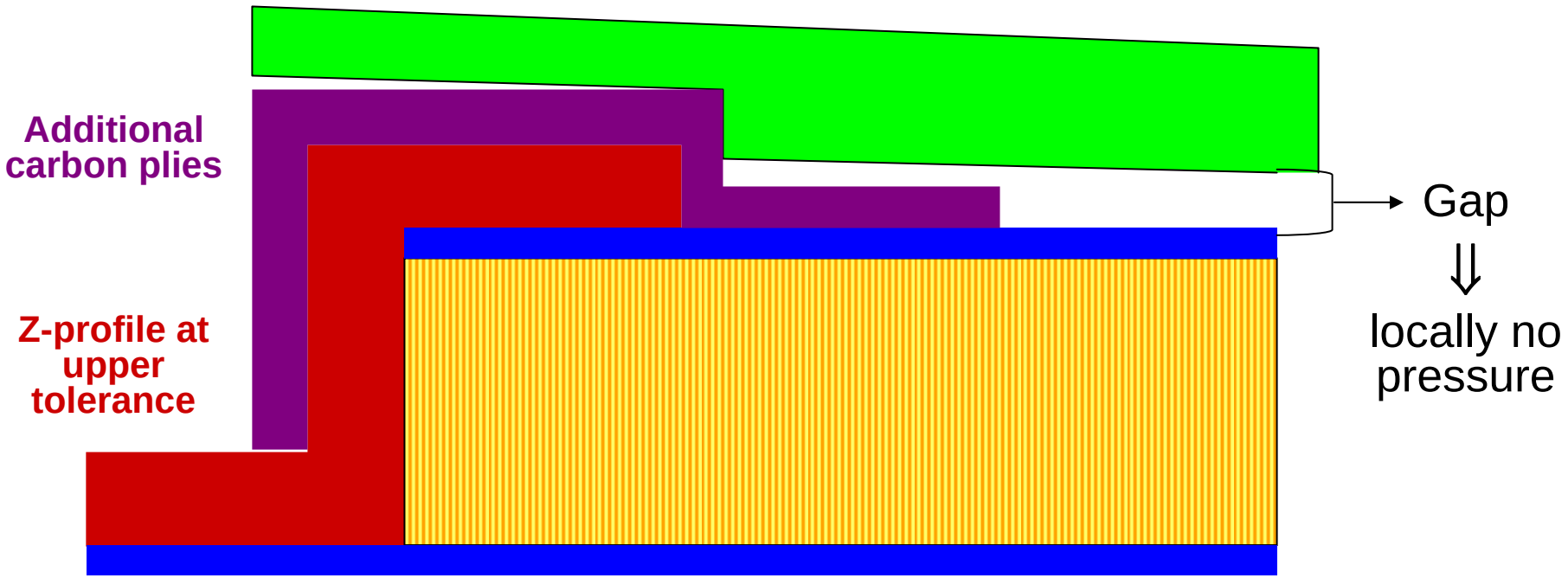
- Tolerances review has indicated that CFRP plate cut-out did not totally compensate higher tolerance Z-profile thickness

- In addition, CFRP plate did not compensate over-thickness at Z-profiles junction, where additional carbon plies are fitted



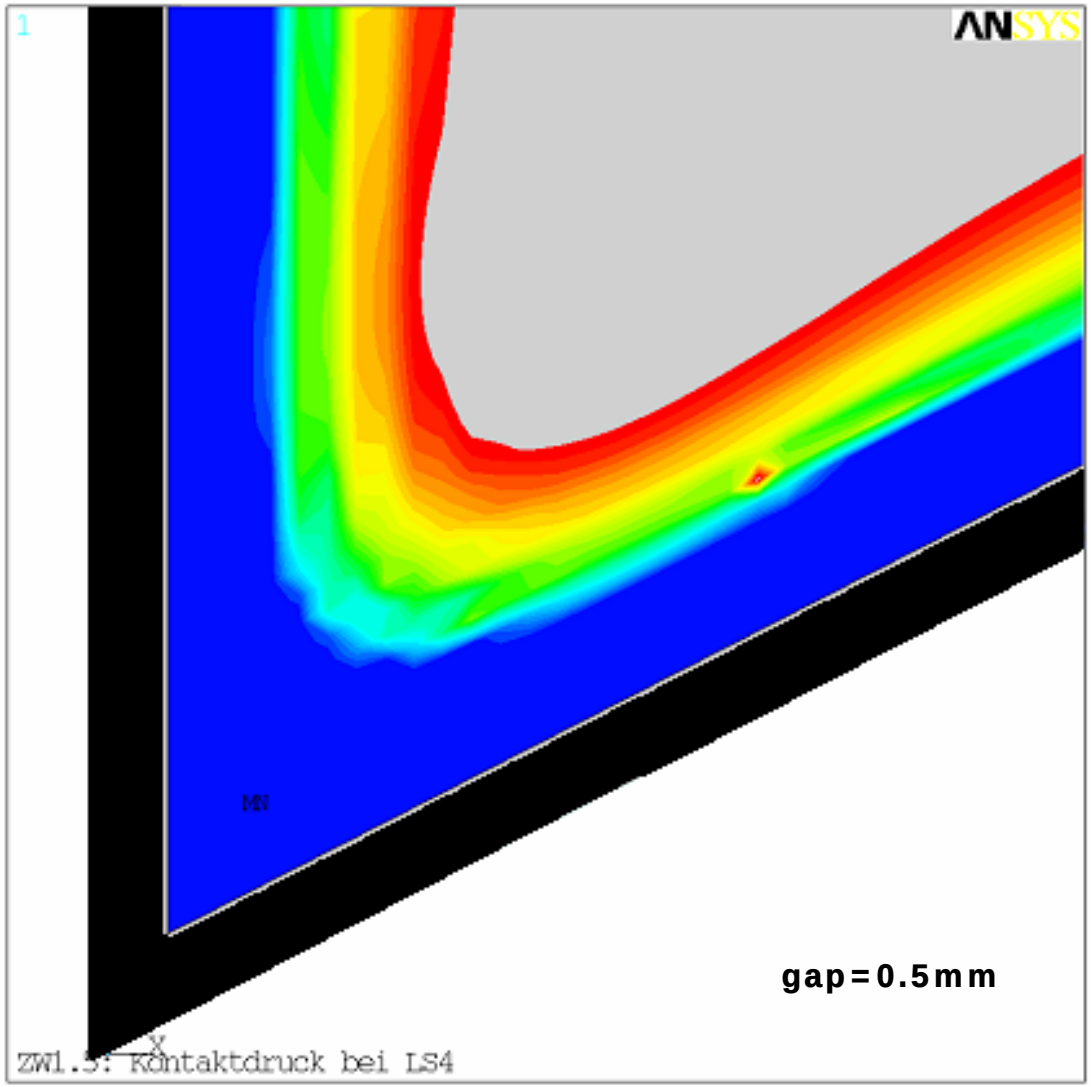
Most likely scenario

Possible lack of compensation during curing



Most likely scenario

Pressure distribution behind Z-profile in case of gap



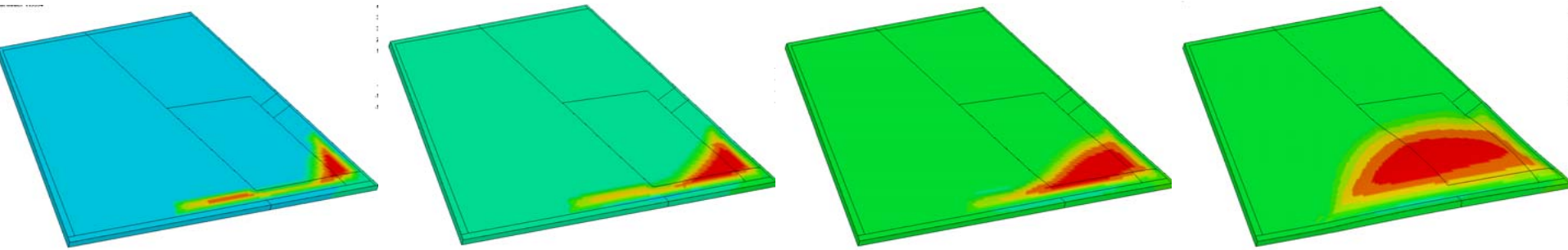
Blue area
=
zero pressure

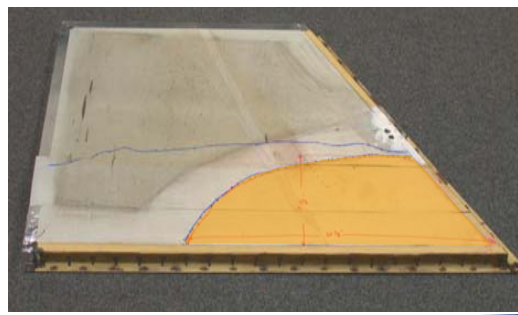
Red area
=
nominal pressure

Most likely scenario

FEM investigation of this scenario

- Rudder damage was accurately reproduced making the hypotheses of an initial disbond :
  - at the additional carbon plies area
  - along the lower spar and front rib 0 Z-profile





Rudder disbond

Summary

- Initiation of a disbond at the edges of the Z-profile is the most likely scenario for the disbond occurrence
- This scenario is also valid for the event of structural failure in flight

- Rudder disbond occurred before hydraulic contamination
- Remains of the rudder that failed in flight do not exhibit a similar hydraulic fluid contamination
  - Rudder did not fail because it was contaminated with hydraulic fluid

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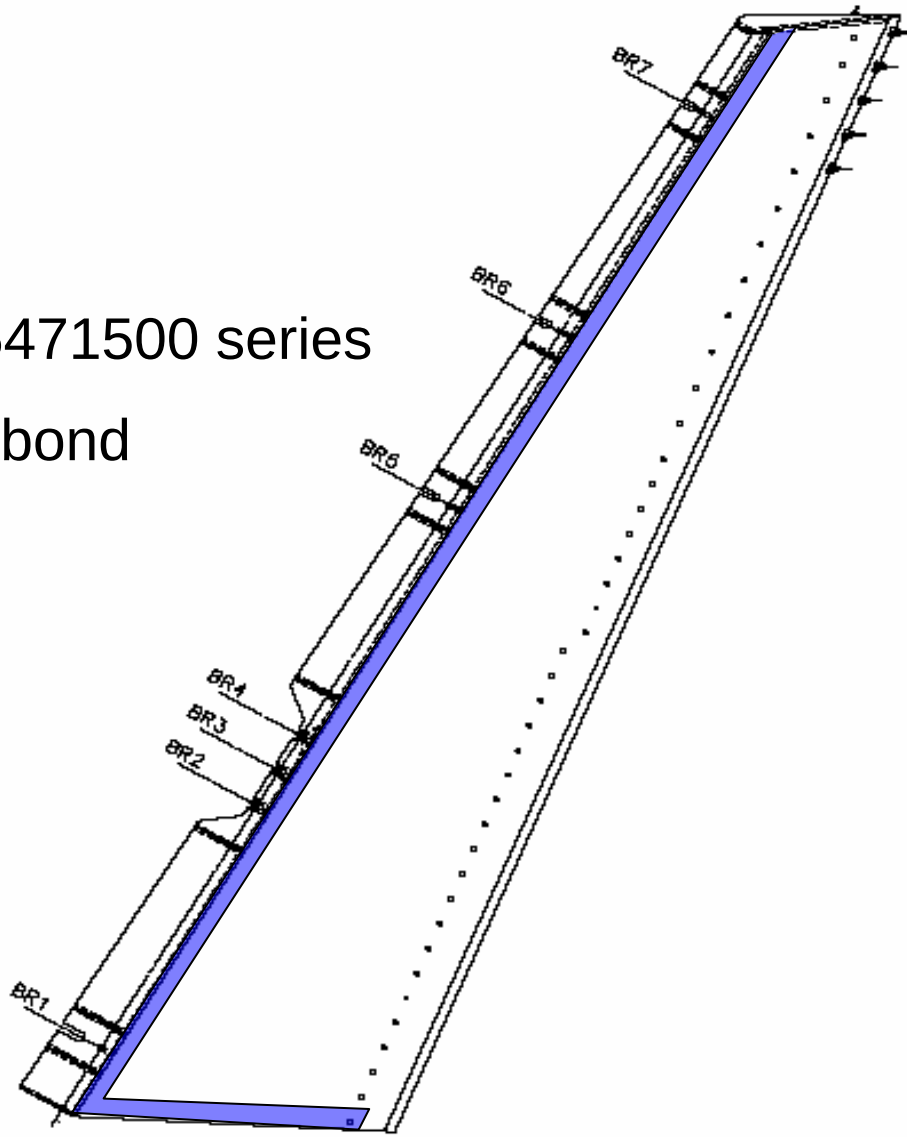
Inspection of Z-profile rudders

Ultrasound inspection

- Inspection of rudders
  - Rudders CFRP rudder PN A55471500 series
  - Repetitive inspection for no disbond initiation adjacent to Z-profile
  - To be launched in mid-2007



Inspection of Z-profile rudders

Inspection principle

- UT at first
- Damage confirmation involves thermography or X-ray
  - To identify nature and actual size of indication
  - To exclude spurious findings from indications
    (e.g. filler, repairs etc)
- Grace period for repair function of severity
- No damage allowed in the long term
- All repairs upon Airbus instructions

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Conclusion

- Sandwich rudders have accumulated a wealth of in-service experience with good results
  - All Airbus fleet composite rudders have accumulated more then 90MFH and 40MFC

- Inspections launched by Airbus have ensured airworthy condition of affected rudders

- Airbus has defined an action plan in order to address the Z-profile issue
- This plan is expected to be put in place in-service by mid-2007