Journée 3AF structure

Louis RATIER Ho generic methods A350

Thermo-mechanical analyses used for Aircraft sizing process

"Thermomécanique des structures aéronautiques et spatiales"

18 nov 2014 ENAC Toulouse

AIRBUS

Thermo-mechanical analyses used for Aircraft sizing process

Content

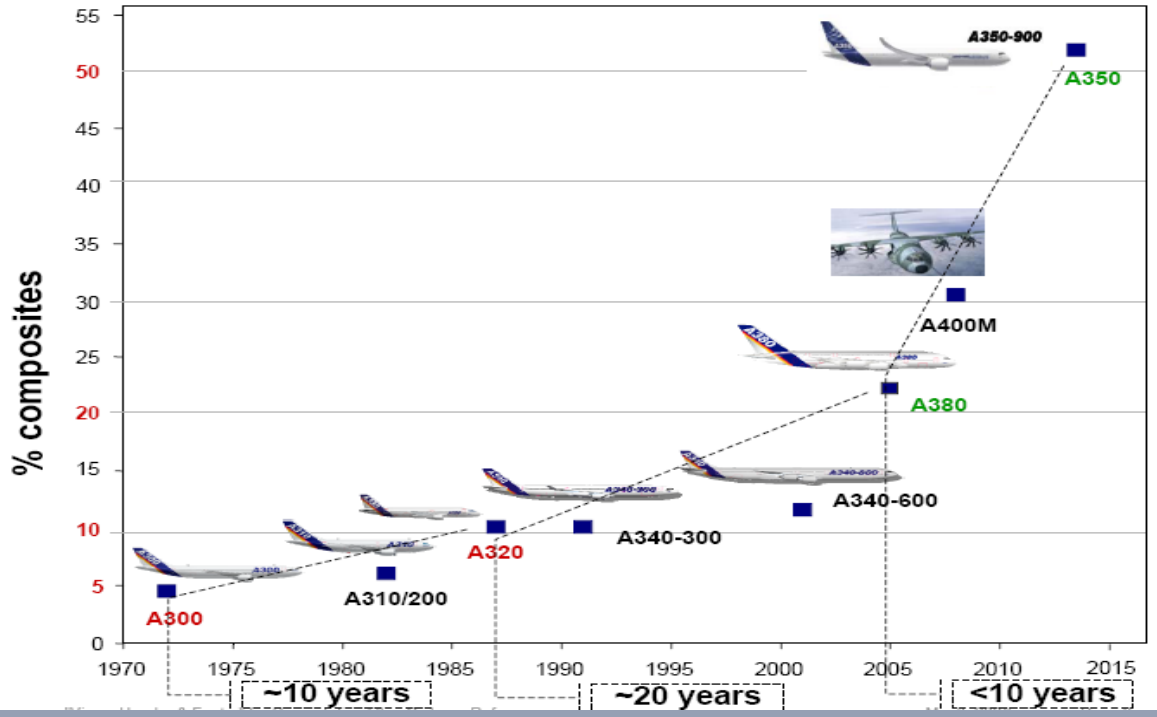
Few lessons learnt from A350 Thermo-mechanical stress modelling

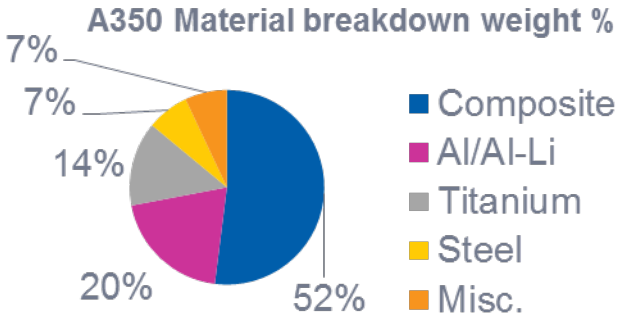
I. Introduction: Thermal effect for hybrid aircraft
II. Thermal global effect / Thermal local effect: Multi-scale approach
III. Global FEM & sizing process
IV. Large Scale Detail FEM: Virtual Full scale test
V. FEM Difficulties: zero stress (Tie condition, …)
VI. Conclusion

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

Introduction: Thermal effect for Hybrid aircraft

- Thermal effects created by coefficient of thermal expansion difference; Typical values are reminded below:
  - Aluminium ~24 10^{-6}/ deg° Celsius
  - Titanium ~ 9 Steel ~11 10^{-6}/ deg° Celsius
  - CFRP ~4 iso layup (2 X oriented, 7, Y oriented) 10^{-6}/ deg° Celsius

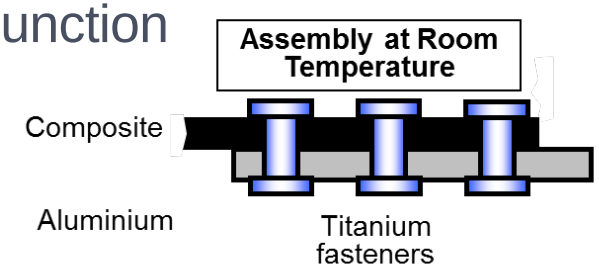


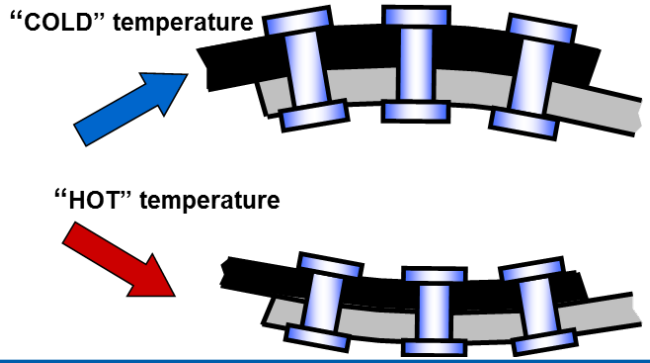


© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

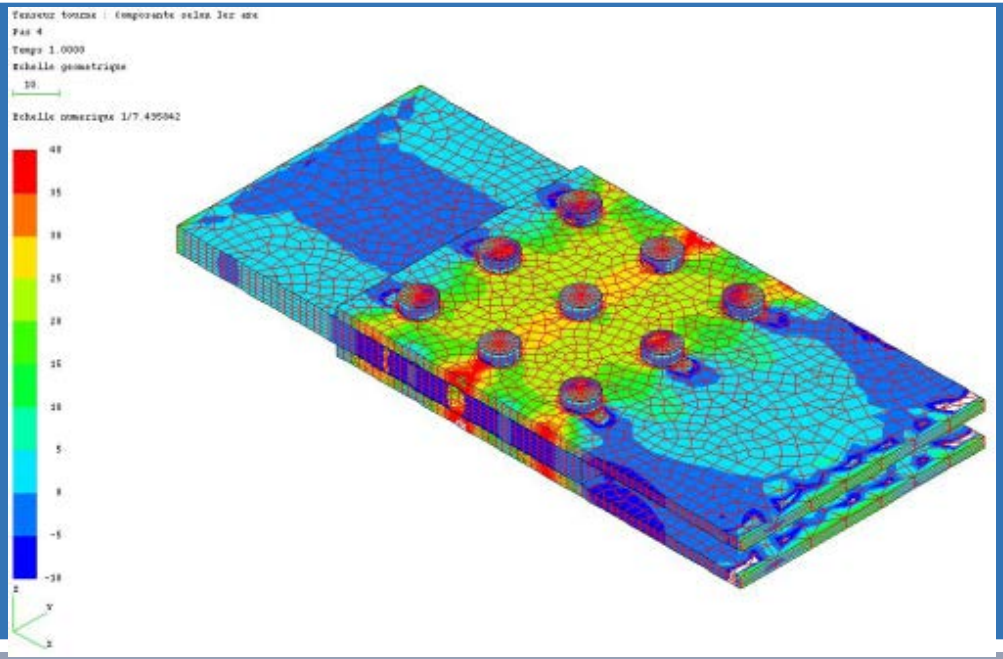
II. Thermal Global/Local effect: Multi-scale approach

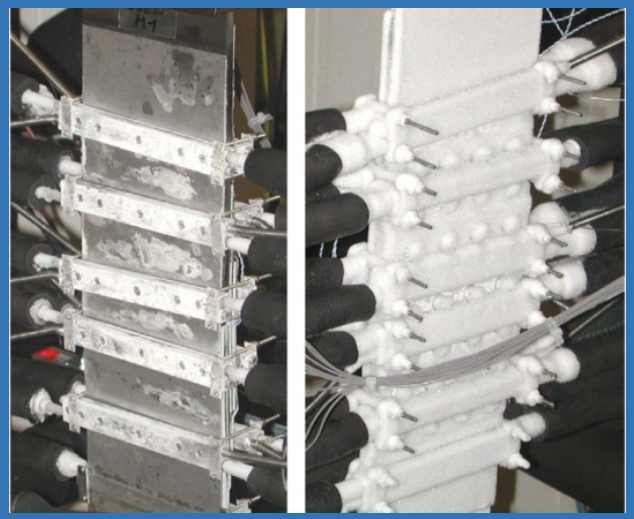
- Local effect: Hybrid junction





Example: Local DFEM used for local thermal effect analysis and validated through test T= -30°C +70°C



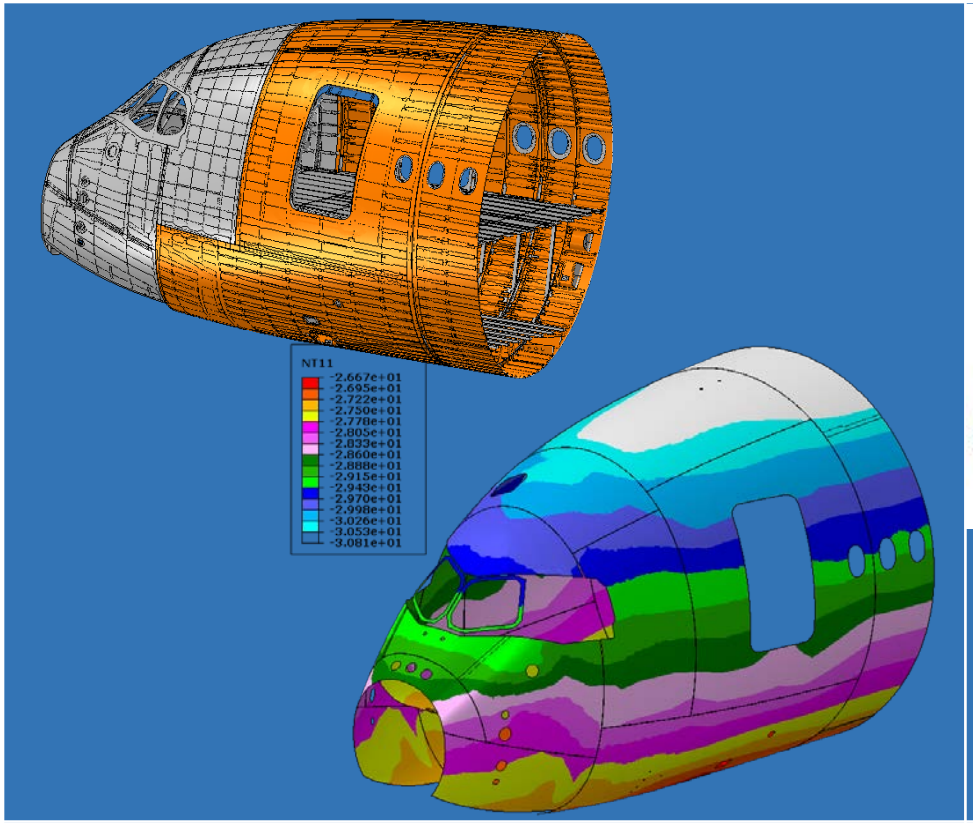


© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

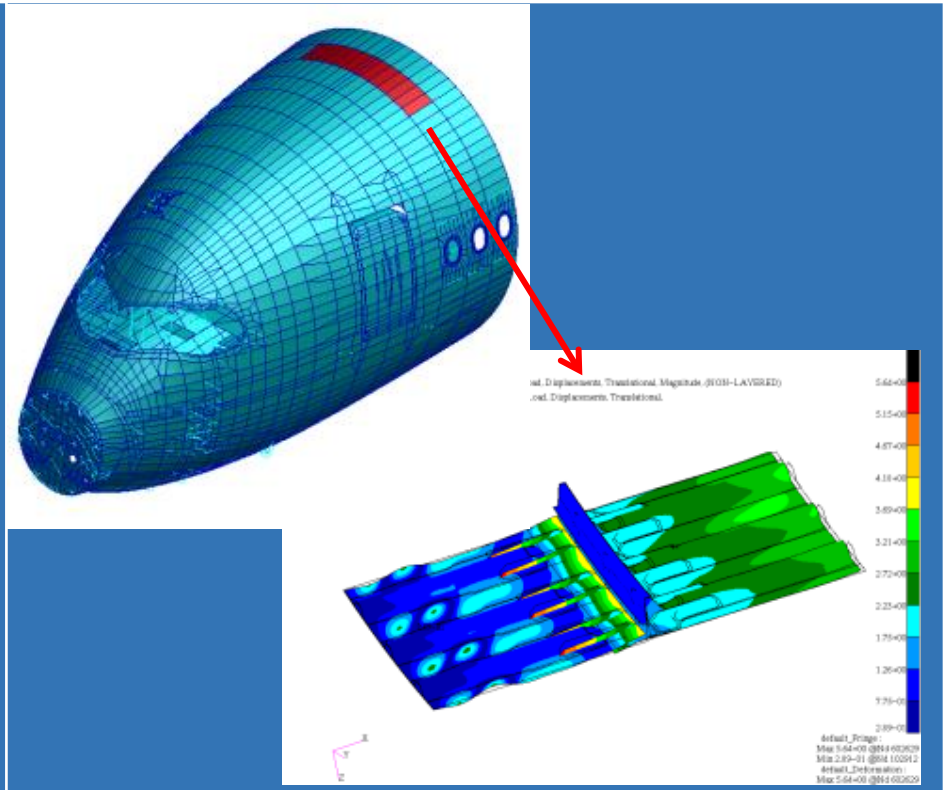
II. Thermal Global/Local effect: Multi-scale approach

- Global effect: load path due to assembly of Aluminium/CFRP subcomponents

Example of Global effect on Nose fuselage: Hybrid junction: Aluminium and CRFP sections



Material break down: Aluminium part in grey/ CFRP in orange
Thermal mapping: typical Polar thermal mission °C



Thermal load path identified on Global FEM, then transfer to local DFEM

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

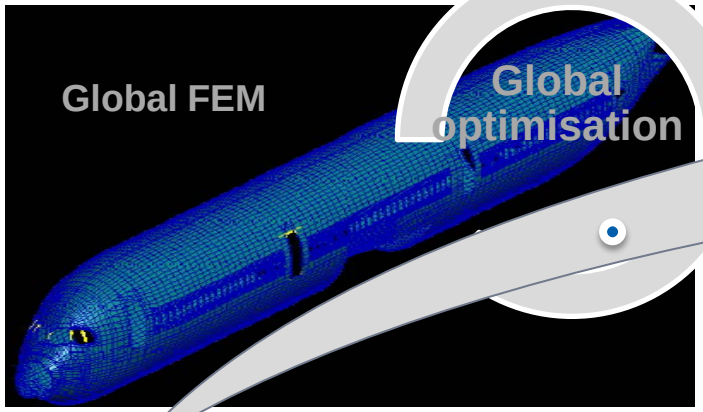
III. Global FEM & sizing process

- A350 Program Milestones/ Global FEM

2006 — 2008 — 2010 — 2012 — 2013 — **2014**

Concept definition — *Detail definition* — ***End of detail definition*** — *Test validation*

Start of production — *Fal Start* — *First Flight* — *Certification& First delivery*



Local optimisation

Weight saving optimisation

Maturity of the design

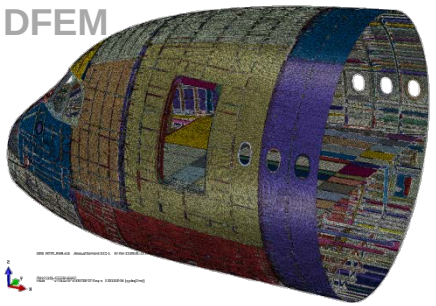
Large detailed FEM

Start of Large DFEM

Delivery of Large DFEM

Results of Large DFEM

Large DFEM



© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

AIRBUS

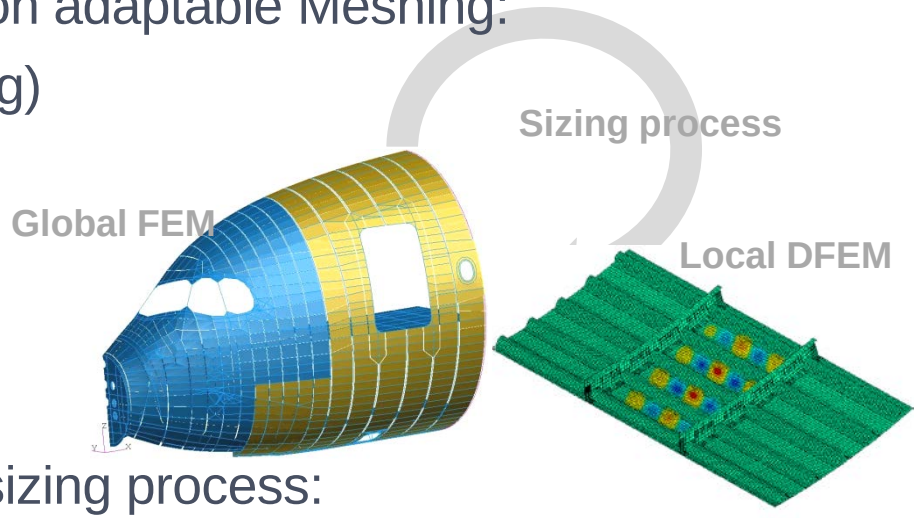
III. GFEM sizing process

- GFEM sizing process

  => Sizing process loops relay on adaptable Meshing:

  GFEM (Gross meshing)

  + Generic Local DFEM



Thermo mechanical specificities n A/C sizing process:

- Sizing process (GFEM / local DFEM) modelling principles are based on extensive experience of Mechanical loading. Thermo-mechanical modelling principles need to be adapted to A350 new hybrid structures: (Hybrid Fuselage nose; Hybrid Wing: Alu Rib/CRFP covers..)
- Difficult set up of Thermal Full scale test

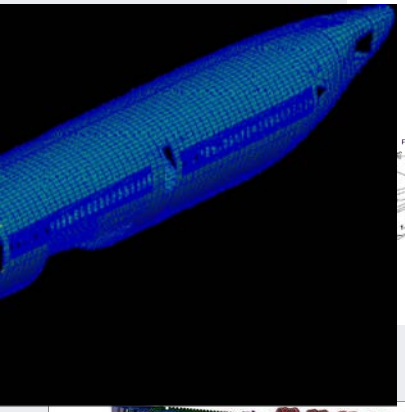
=> See examples next slides (Rear fuselage alu Frame; Wing Ribs)

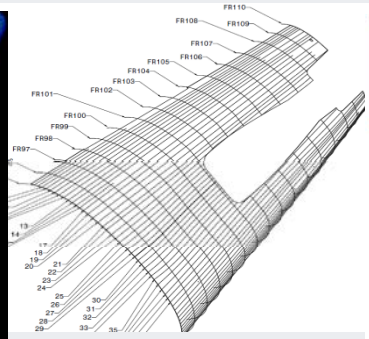
© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

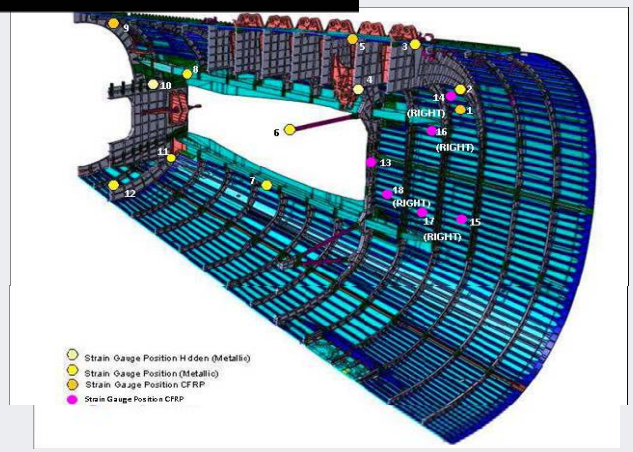
III. GFEM sizing process

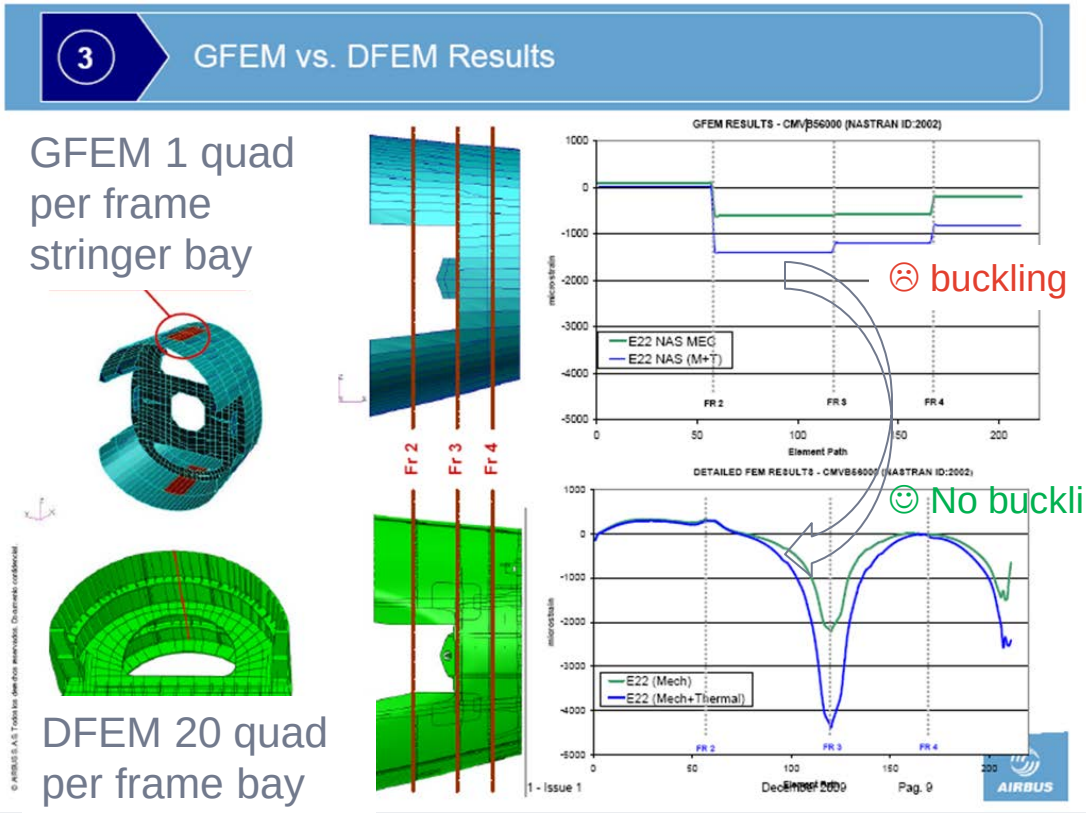
- Example of A380 Thermal analysis difficulties: Rear fuselage example

GFEM: 1 element per frame bay=> Thermal effect maximised/ skin buckling criteria







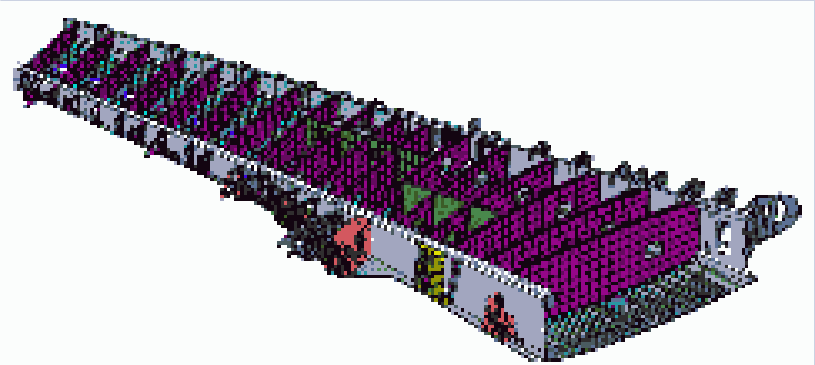
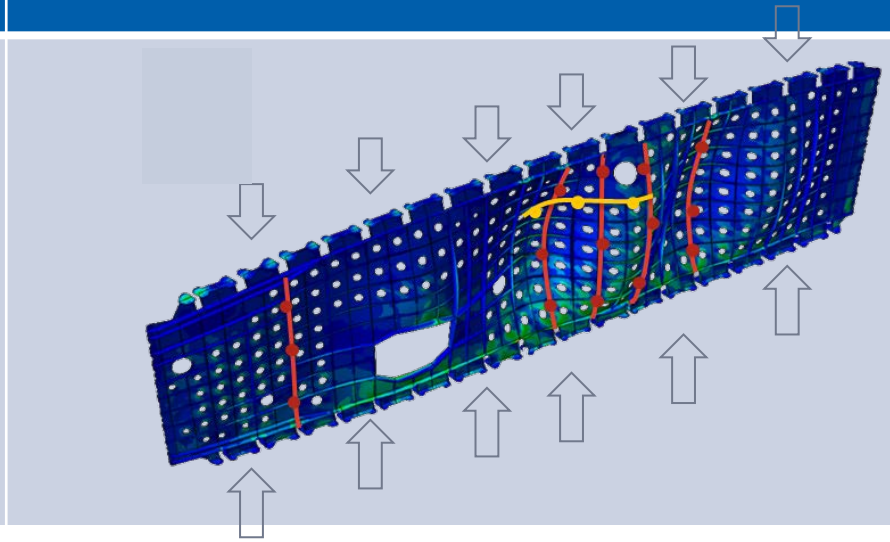


➔ Meshing Refinement to be implemented for hybrid junction

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

III. GFEM sizing process

- Example of Thermal analysis difficulties: A350 Wing box example (Aluminium Rib surrounded by CFRP covers & spars)

Aluminium Rib pink surrounded by CFRP box (covers green &Spars grey)	Hot thermal effect lead to compression of the rib and out of plane displacement
	

Thermal hot loading => Compression ≠ Mechanical loading=> Shear & Tension

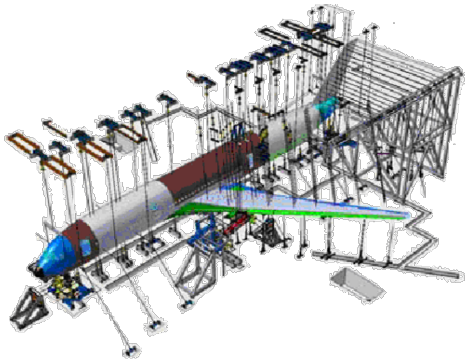
➔ Modelling rules to be adapted to capture unusual out of plane displacement

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

III. GFEM sizing process

- Validation through Major test

  Difficulties to test full scale test under thermal environment



Major test (T=20°) without thermal effects

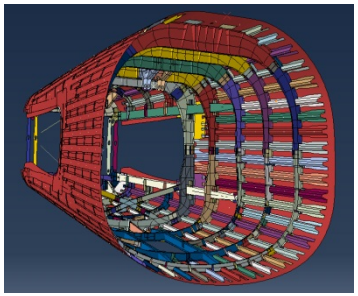
=> Need to anticipate the test validation

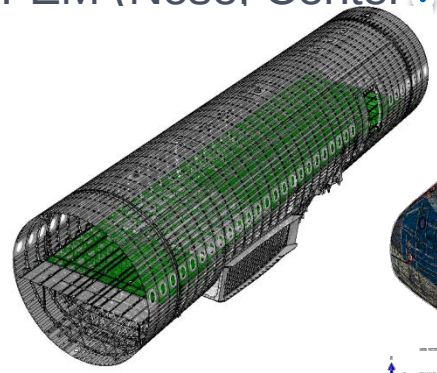
© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

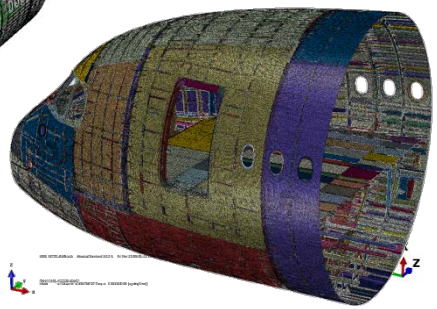
IV. Large Scale Detail FEM

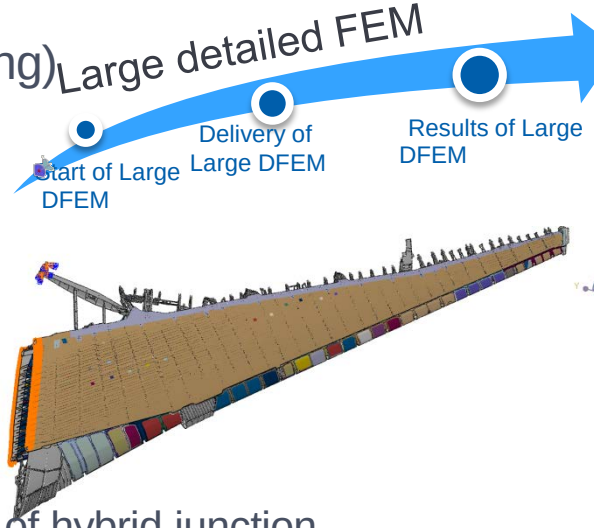
- Requirements:
  - Thermal Virtual full scale test (Limited time scale)
  - Refined modelling of hybrid junction (hybrid junction spread all over the A/C)
  - Identify unusual phenomenon if any (Distortion, out of plane displacement .buckling…)

- Large Scale Detail FEM (Nose, Center Rear fuselage &Wing)









  - Model representative of full section to analyse Global effect of hybrid junction
  - Refinement of hybrid junction
  - NLFEM

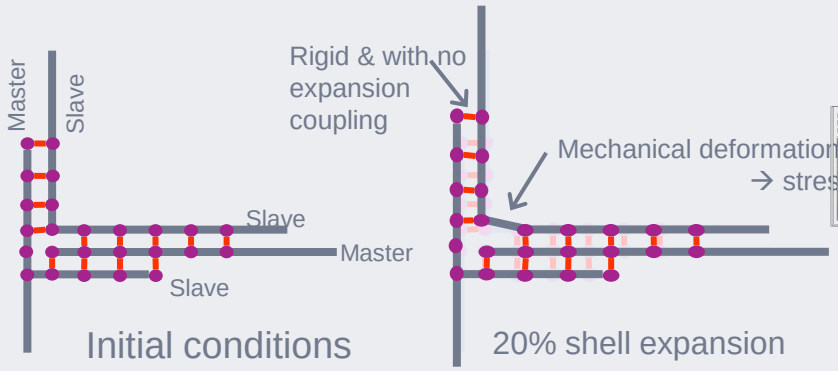
© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

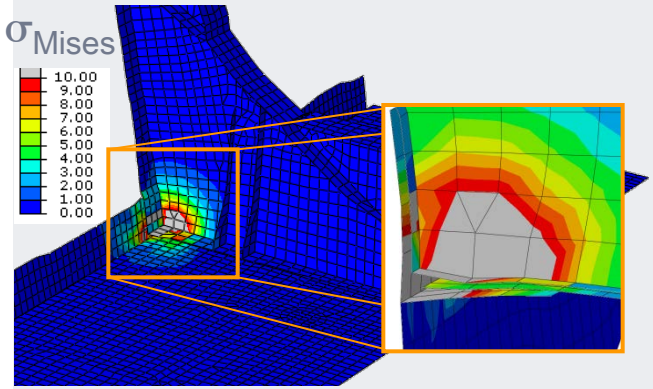
AIRBUS

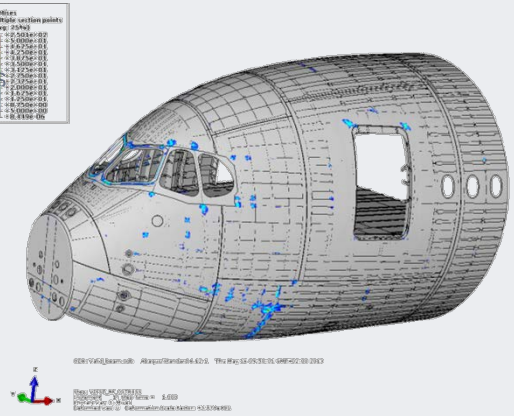
IV. Large Scale Detail FEM

- Highlight on specific thermo-mechanical modelling specificity: Distortion induced by TIE Condition highlighted on a sub-model of three parts linked by three TIEs

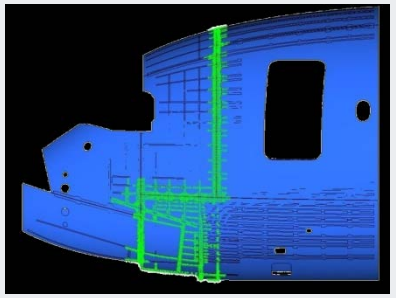
TIE conditions do not take into account the thickness expansion of the parts, thus some distortion appear: Zero Stress check (homogenous Coef. Thermal Expansion DT°=-50°)







Error on local stresses around hybrid junction (increased by meshing refinement)

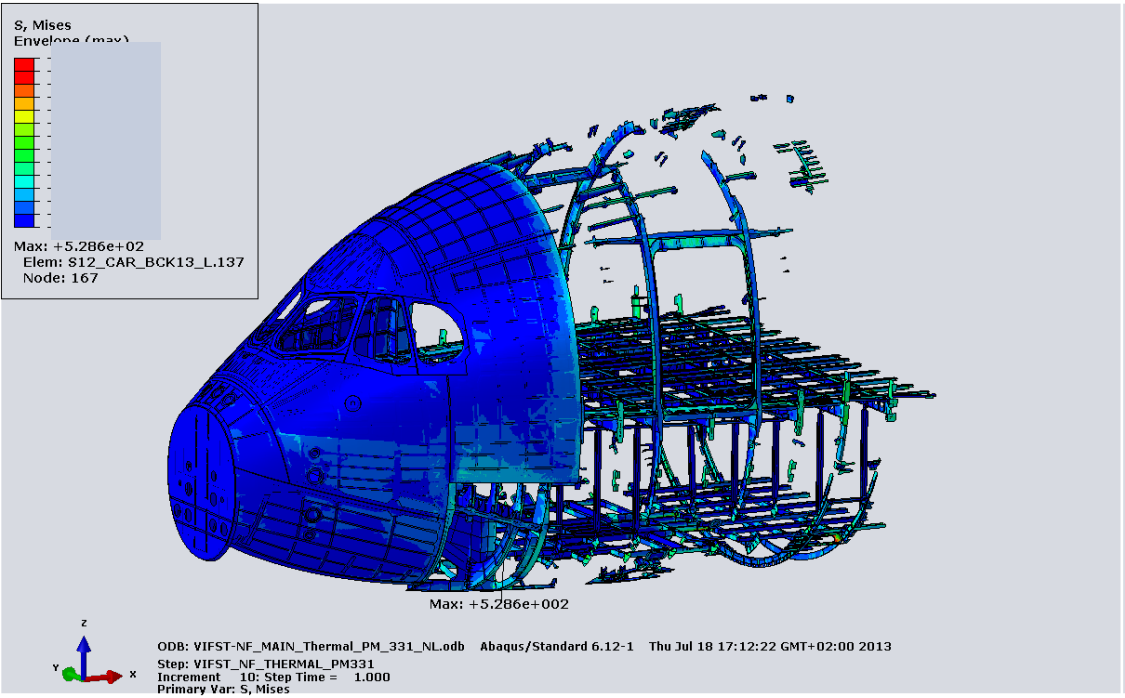


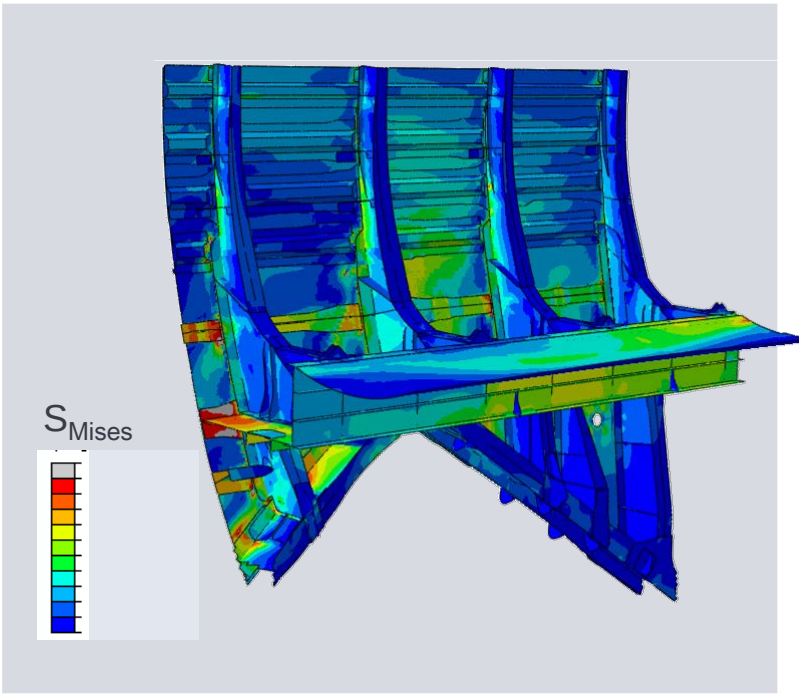
Introduction of fasteners on hybrid junction

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

IV. Large Scale Detail FEM

- Example of Large Scale DFEM Results





Typical stress on metallic parts for cold environment conditions :

- **Identification of hot spot points**
- **Combination with correlated mechanical loading (flight pressure load; ground mecha. Loads …)**
- **Both Extreme Static loads & Average Fatigue loads**

Typical stress on metallic frames attached to CFRP Skin for Hot environmental conditions

- **Identification of local stress concentration areas**

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

V. Conclusion

Few lessons learnt from A350 Thermo-mechanical stress modelling

- Time scale constraint for large scale DFEM => Multi Model analysis
- Multi-scale analysis to deal with local/global Thermal effects;
- NL analysis to deal with unusual load path
- Specific refinement of hybrid junction
- Virtual testing to complement Major test demonstration

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document.

© AIRBUS Operations S.A.S. All rights reserved. Confidential and proprietary document. This document and all information contained herein is the sole property of AIRBUS Operations S.A.S. No intellectual property rights are granted by the delivery of this document or the disclosure of its content. This document shall not be reproduced or disclosed to a third party without the express written consent of AIRBUS Operations S.A.S. This document and its content shall not be used for any purpose other than that for which it is supplied. The statements made herein do not constitute an offer. They are based on the mentioned assumptions and are expressed in good faith. Where the supporting grounds for these statements are not shown, AIRBUS Operations S.A.S will be pleased to explain the basis thereof. AIRBUS, its logo, A300, A310, A318, A319, A320, A321, A330, A340, A350, A380, A400M are registered trademarks.