NUMERICAL APPROACH FOR STIFFENER DEBONDING PREDICTION OF AIRCRAFT COMPOSITE STRUCTURES

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CONTEXT

Reducing carbon footprint of aviation

→ Weight reduction → Large use of composite material

Regulations demand to predict failure with respect to different loading, defaults, impacts.

→ Experimental approach
→ Numerical approach

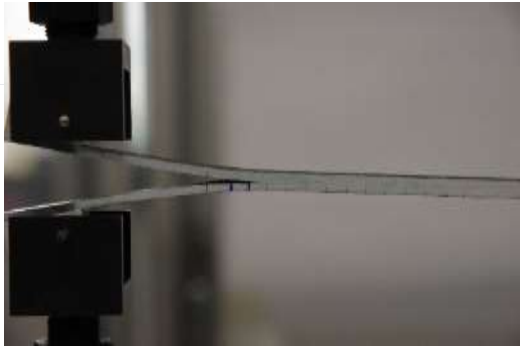
Industrial simulation tool

→ requires compromise between accuracy and cost.
  → Model complexity, parameters identification, computation time, engineering pre and post processing

Use case : Stiffener pull-out

Stiffeners bonded on cured skin, CFRP TS material

METHODOLOGY



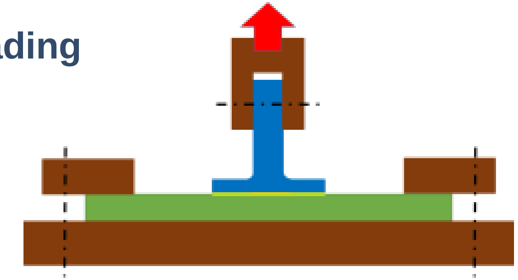
Elementary scale → **Failure mode parameter identification**

DCB, MMB

Delamination, cracks,
mode I → mixed mode → mode II

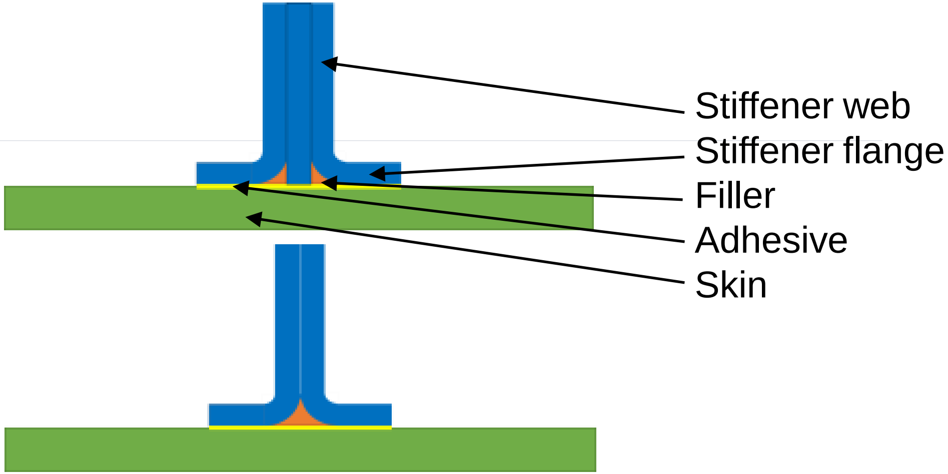
Technological sample → **Complex loading**

Transverse tension, Pull-out



Simulation allows understanding different phenomena that occur during tests

MODEL



For the structure (Stiffener, filler, skin):

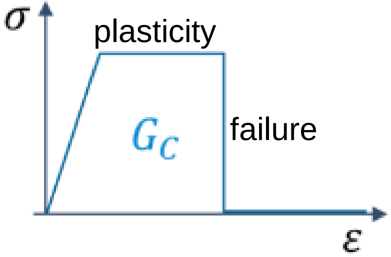
- Linear elasticity
- Large displacement

For dedicated zones (interfaces):

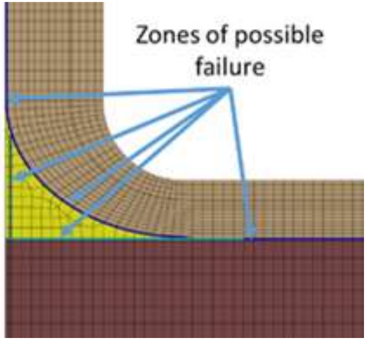
- 3D with only out of plane behavior

$$\sigma = \begin{pmatrix} 0 & 0 & \sigma_{13} \\ 0 & 0 & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{pmatrix}$$

- Progressive alteration of mechanical properties
  - ➢ Plasticity (Hoffman)



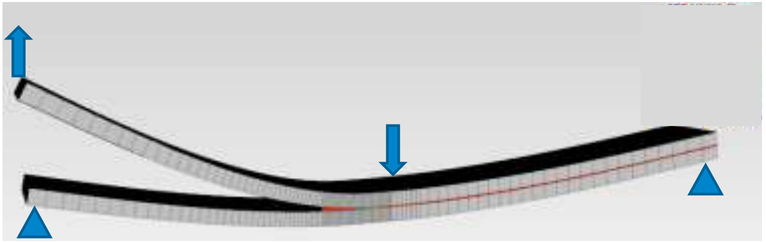
- Local failure
  - ➢ Criterion based on energy-release rate
  - ➢ Deleting FE interface elements

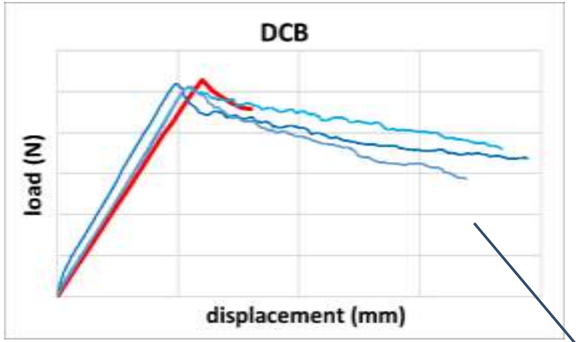


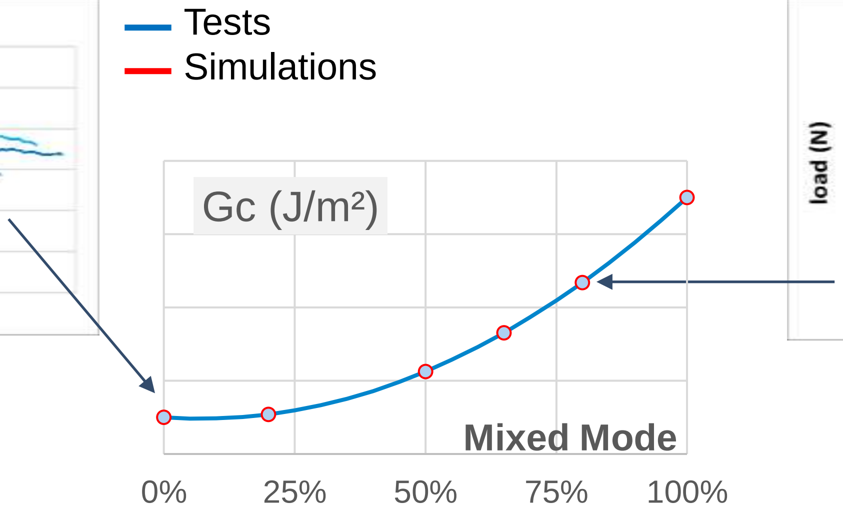
DASSAULT AVIATION

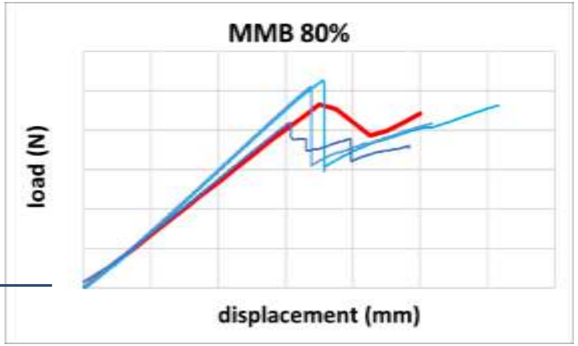
ELEMENTARY TESTS
DCB : DOUBLE CANTILEVER BEAM

MMB : MIXED MODE BEAM









Tests from
BDYN, ONERA, ISAE
With support of DGAC

DASSAULT AVIATION

TRANSVERSE TENSION (MIXITY MODE 60%)

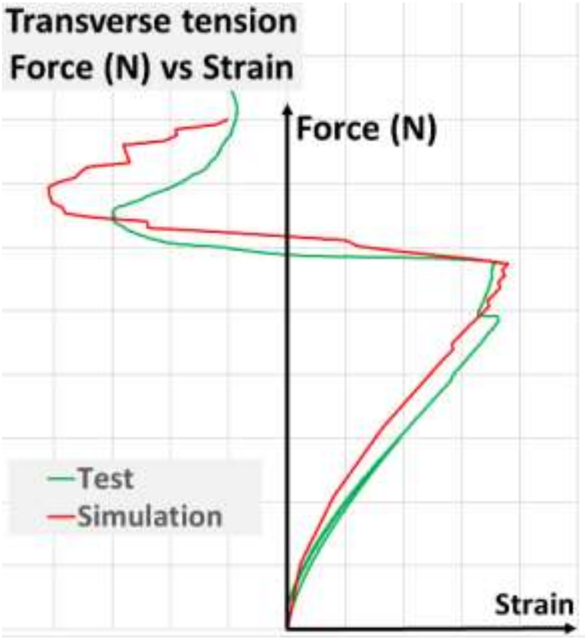
Assumptions, cohesive zone :

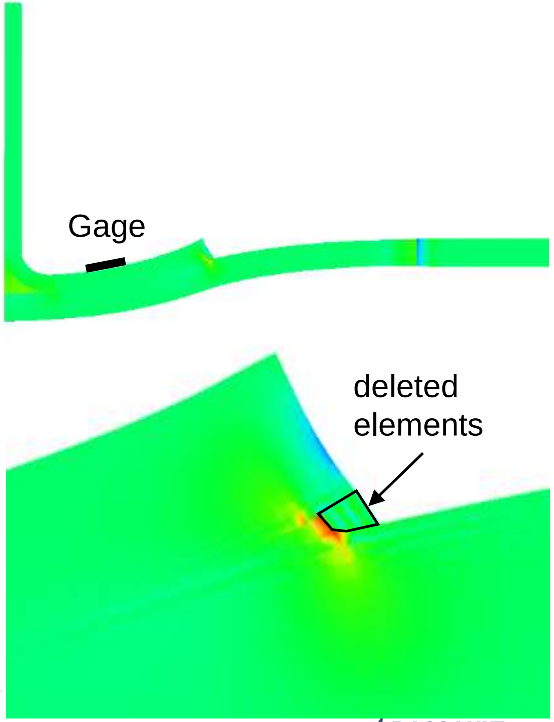
Junction Stiffener-flange/skin
(Adhesive zone)

Results

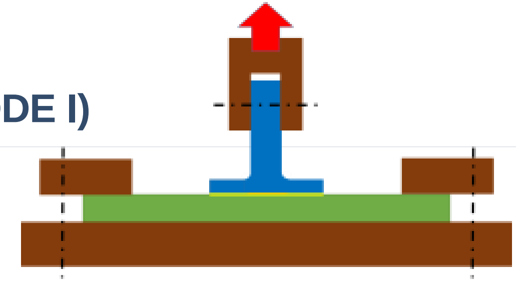
With parameters extracted from elementary tests:

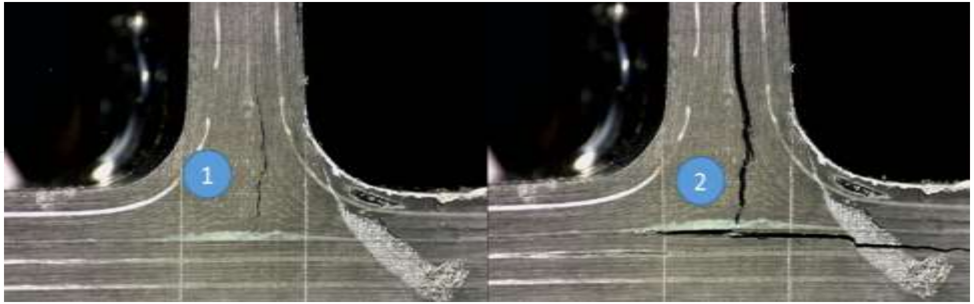
- Good correlation between test and simulation
- Good description of debonding initiation and propagation





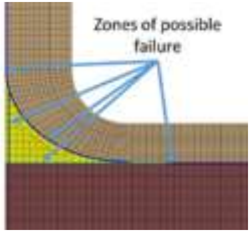
PULL-OUT (MODE I)



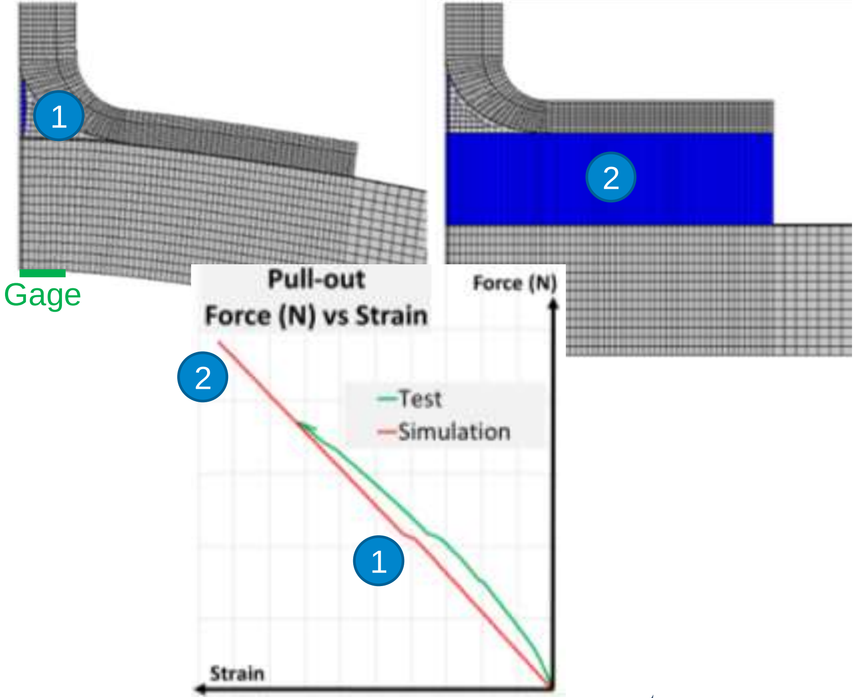


Assumptions

Interfaces:



- Junction left-web/right-web
- Filler zone
- Junction radius/filler
- Junction Stiffener/skin



Results

1 Resin crack in filler zone

2 Debonding: start under filler and propagate up to flange extremity

Obtaining good correlation between test and simulation requires specific values of G1c not consistent with elementary tests (180% deviation).

DASSAULT AVIATION

CONCLUSION

Our elementary tests (DCB, MMB) give energy-release rate (Gc) for interface 0°/0°.

Transverse tension case

- Simulations give good predictions of failure initiation and propagation, for different configurations.

Pull-out case

- Simulations allow understanding and localization (the filler) of the failure mode for different configurations.
- Simulations suggest the introduction of a specific G1c in the filler lower than those given by DCB.

Investigations are undertaken :

- Need of a characterization for 90° layup (the filler zone), more representative than 0° standards
- Considering
  - Fragile failure of 90° UD instead of DCB values
  - Manufacturing thermo-mechanical initial stress
  - Interaction of intra-ply / inter-ply damages.

Thank you for your attention