Static failure in components made of Al-Li AA2050 and Al AA7050 alloys

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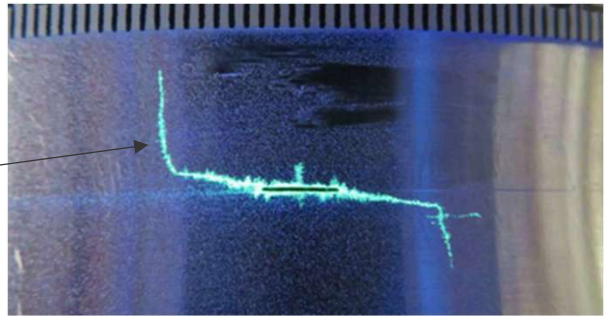
Background and main issues

- Al-Li AA2050-T84 is superior to Al AA7050-T7451 regarding
  - Tensile strength
  - Stiffness
  - Density
  - Fatigure crack growth rate
- Cracks in AA2050 have shown a tendency to turn towards the material L-direction in
  - residual strength test
  - during fatigue crack growth
- Does the same phenomenon occur in static failure without previous crack growth?
- Are traditional sizing methods yet conservative?

Crack turning during fatigue crack growth

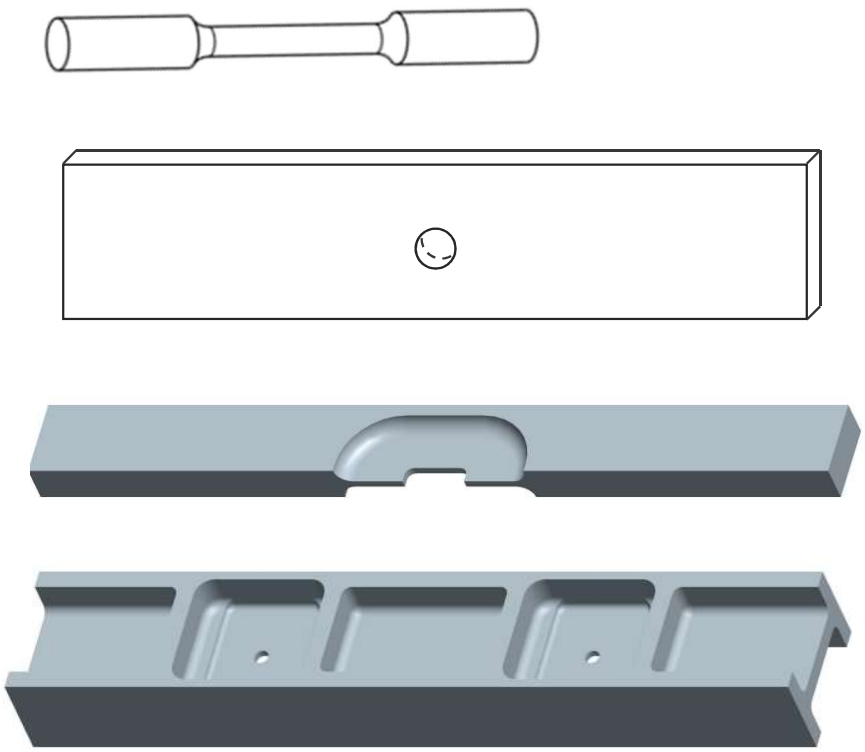


Crack turning in residual fracture

Fracture originating from notch without defect.

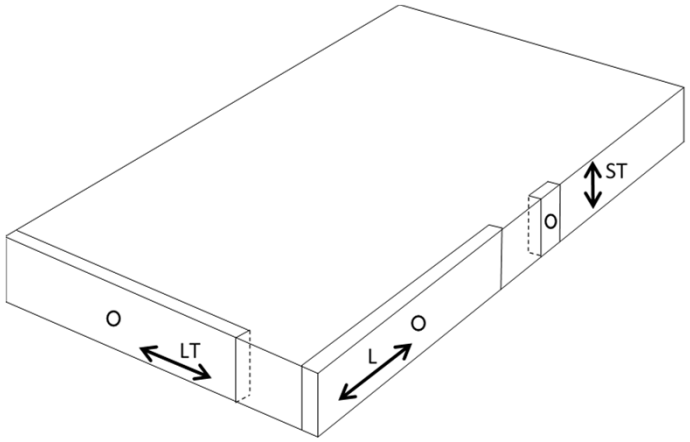
Physical tests and numerical analyses

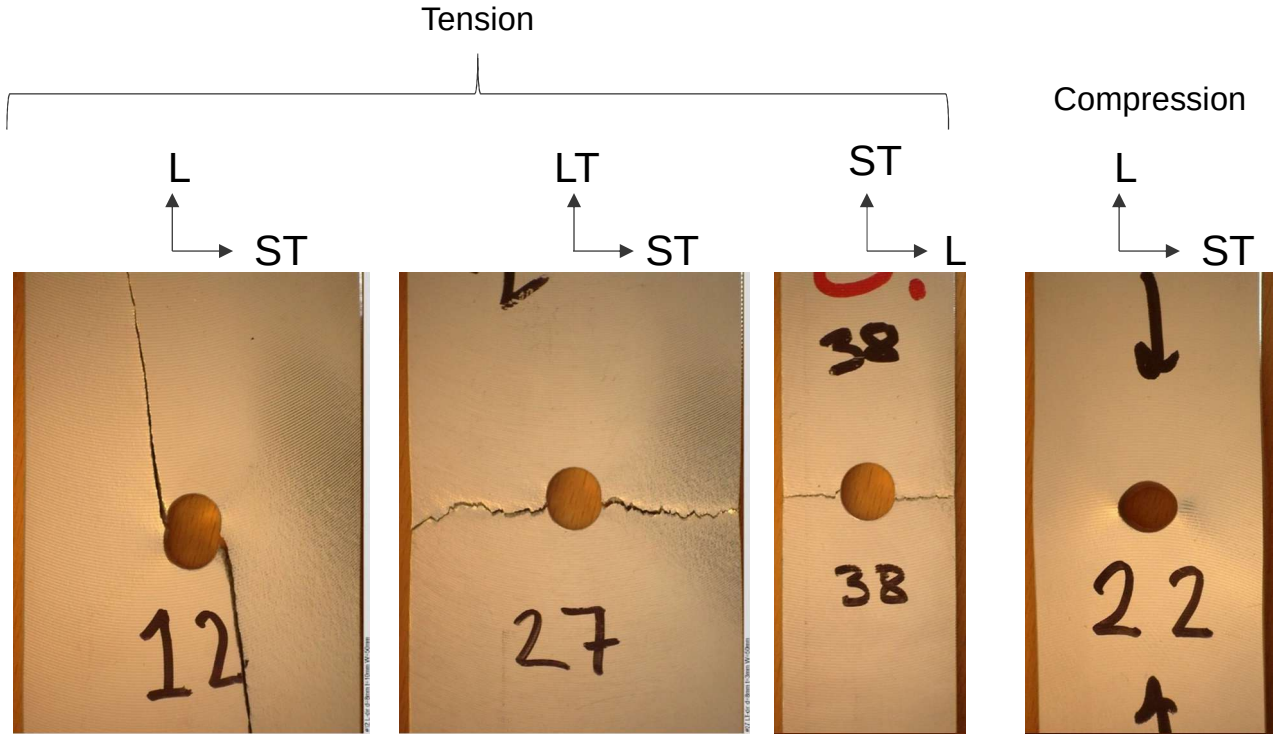
- Several non-standard tests were carried out in this investigation
- Physical tests
  - Reference tensile tests
  - Notched tensile tests
  - Bending tests
  - Bend-shear tests
- Al-Li AA2050-T84 and Al AA7050-T7451
- Test results were compared with
  - Analytical predictions
  - Finite element analyses



Notched tensile tests

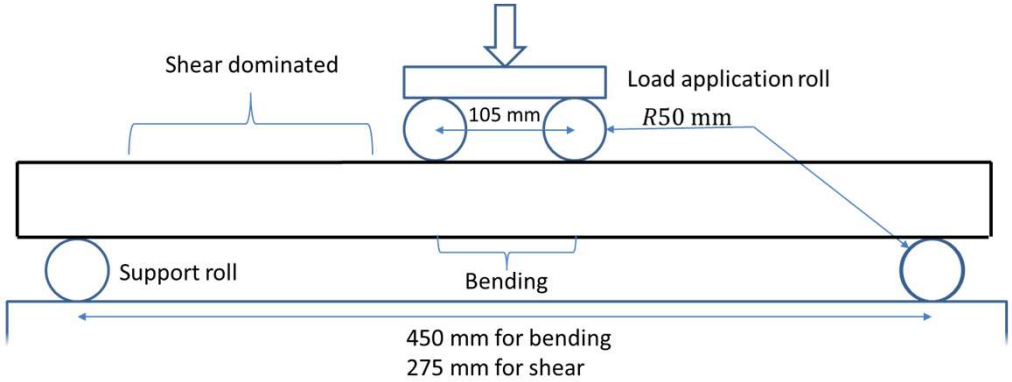
- Open and filled hole
- Material directions L, LT, ST
- Variety of D/W and thickness
- Failure load close to $F = R_m A_{net}$
- Tension and compression

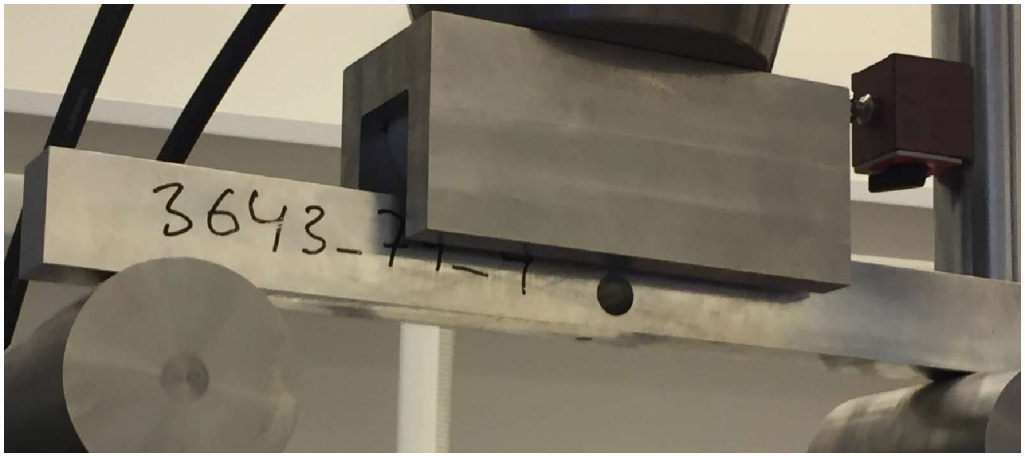




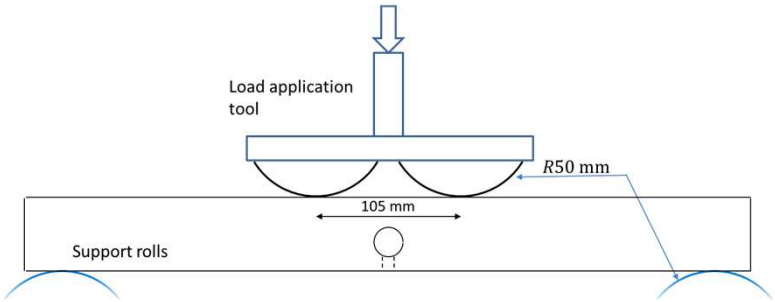
Notched bending tests

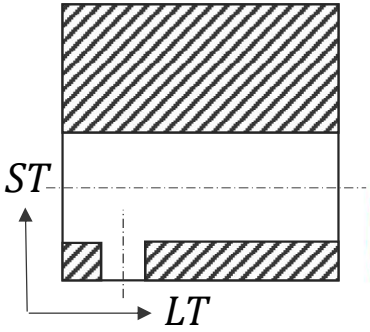
- A four point bending test rig was developed
- Specimens with geometric features
  - Beams with holes (bending)
  - Beams with notches (bending)
  - I-sections with holes (shear)
- Specimens made of
  - AA7050-T7451
  - AA2050-T84



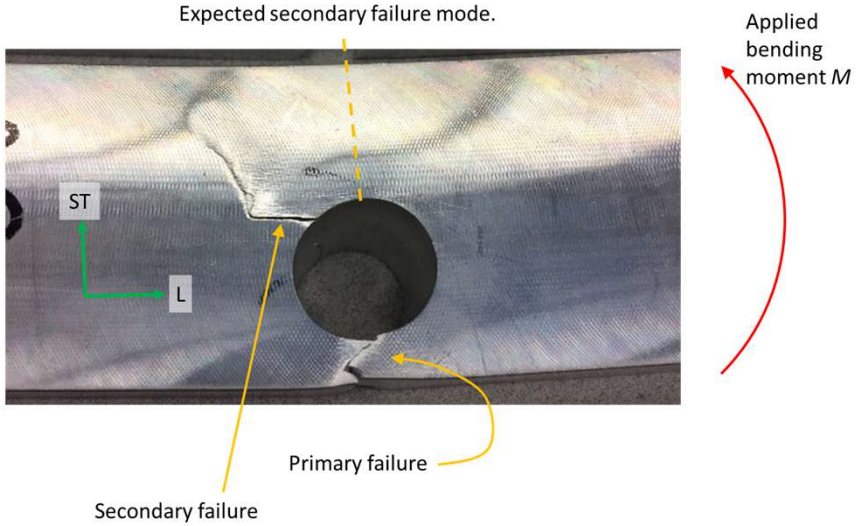


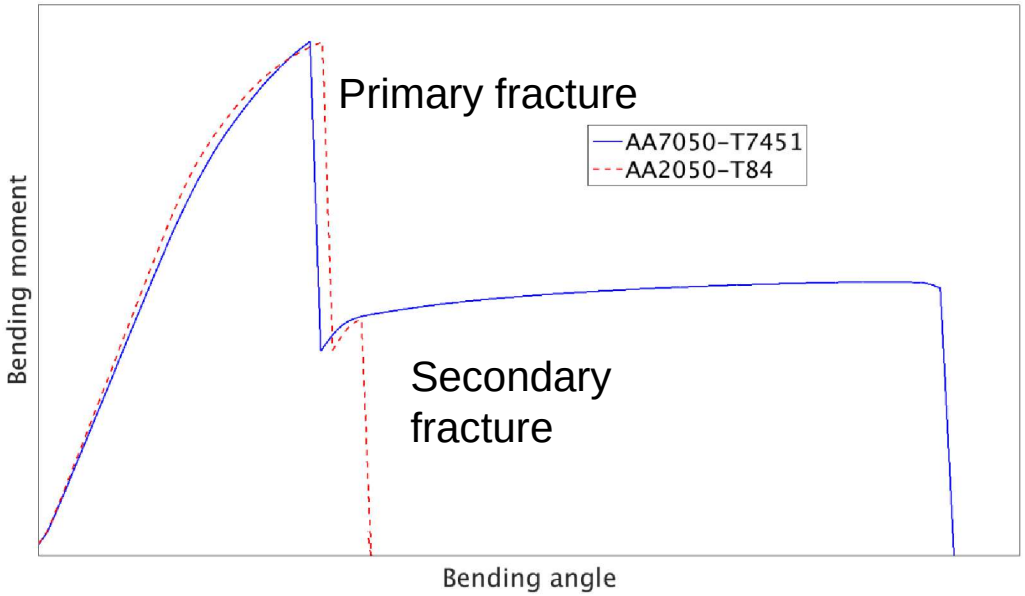
Bending tests with holes



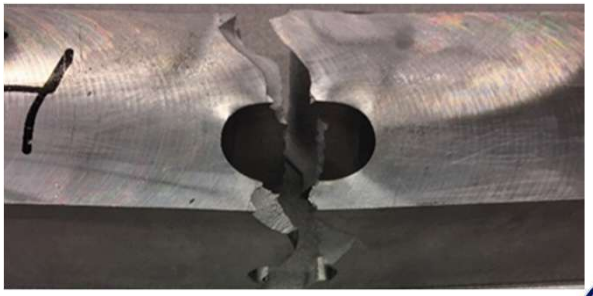


AA2050-T84

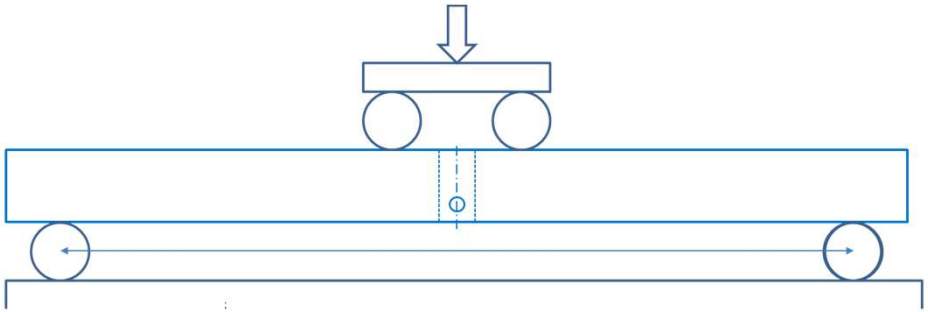


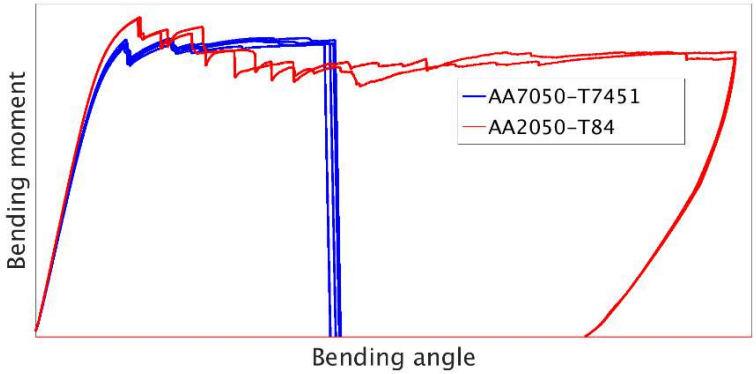


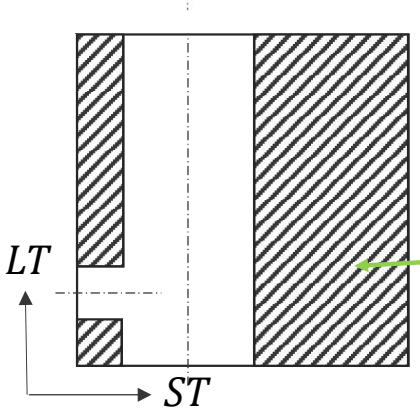
AA7050-T7451



Bending tests with holes

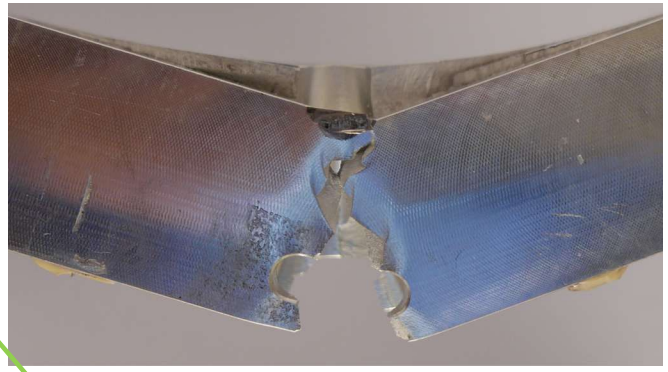






No failure in Al-Li

AA2050-T84



AA7050-T7451

Progressive failure

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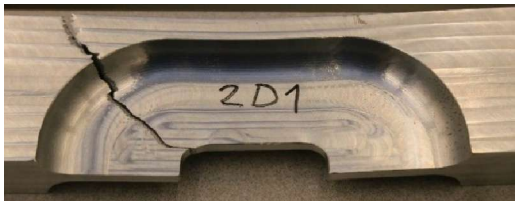
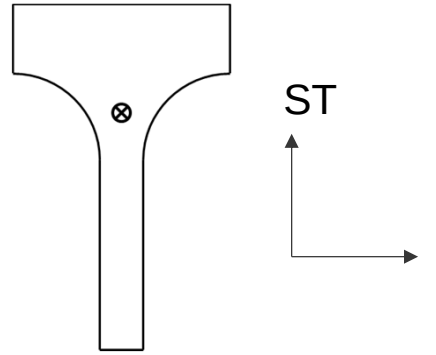
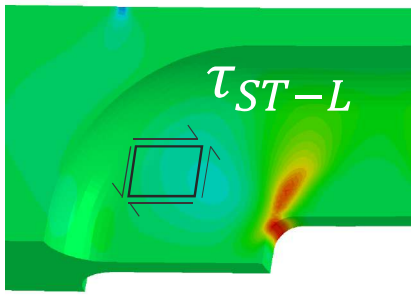
Bending tests with notches

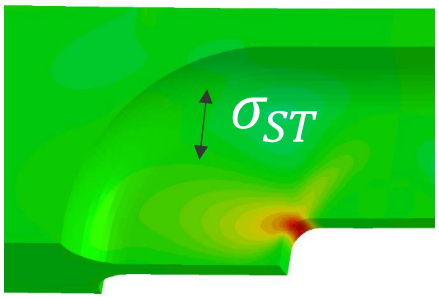
AA2050-T84

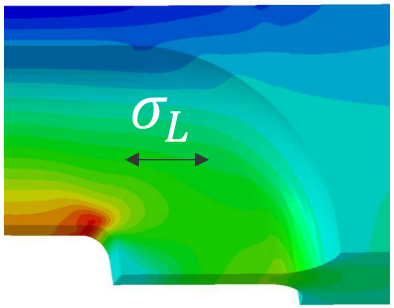


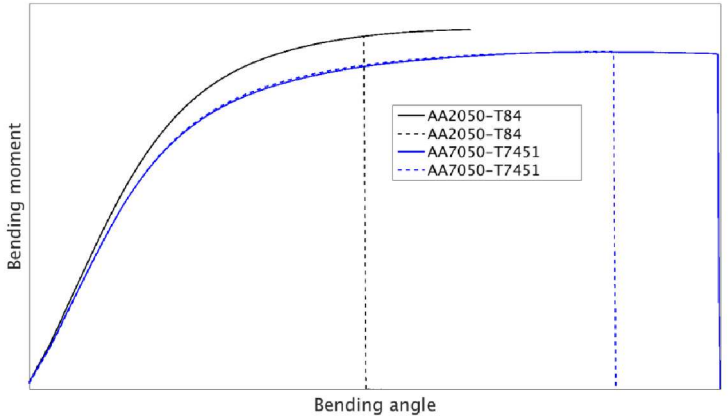
AA7050-T7451







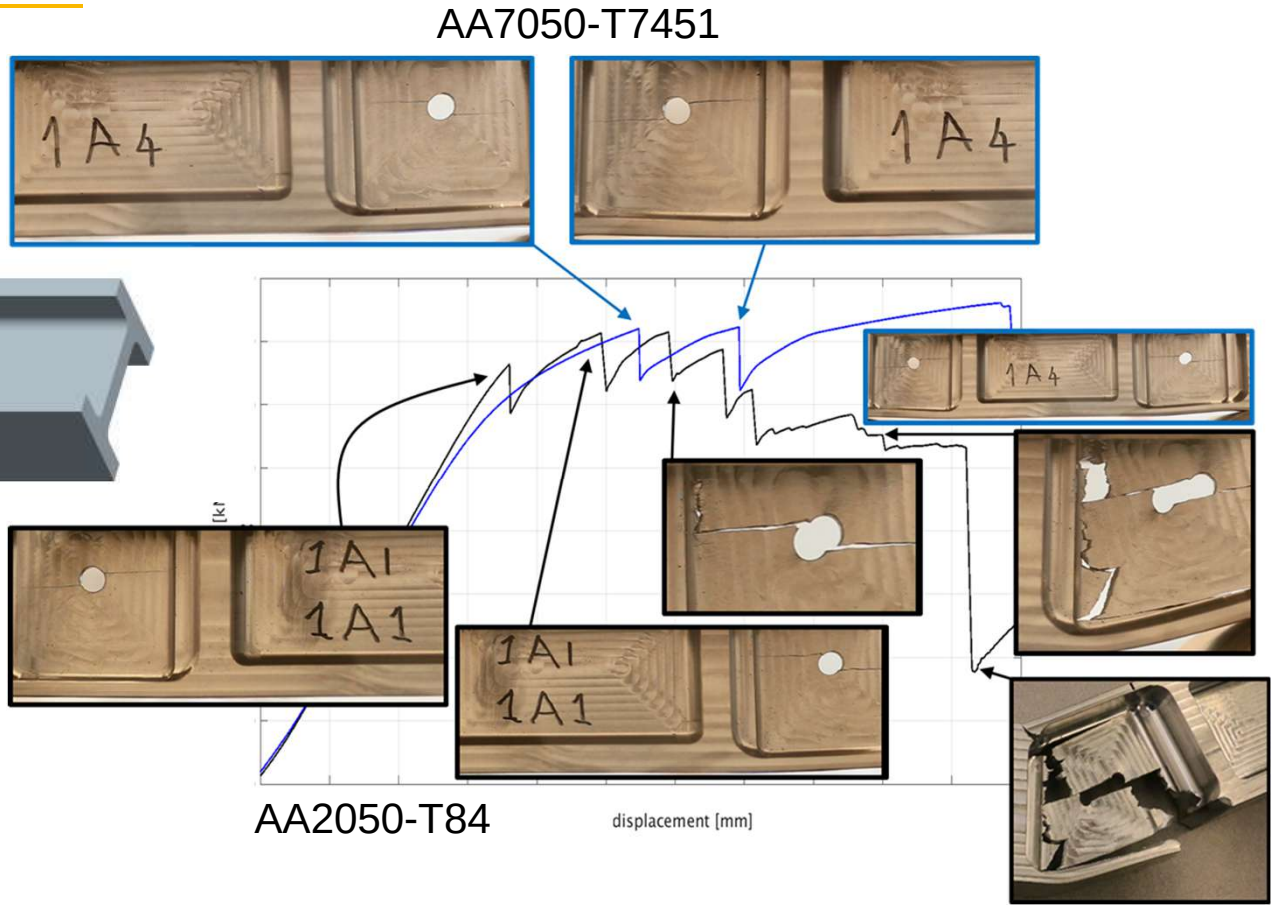




Bending shear test with holes

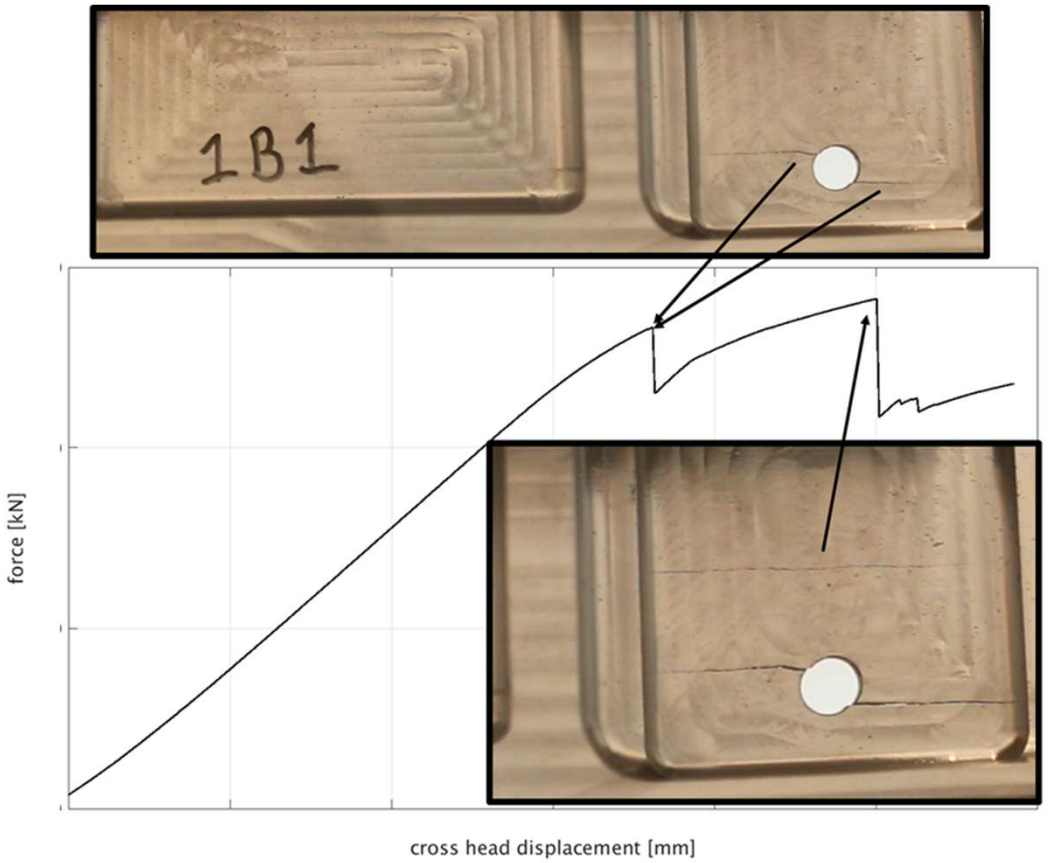
- Shear with stress concentration
- Notch sensitivity

- Cracking along L in both materials
- AA7050-T7451 went through a larger overall plastic deformation than AA2050-T85



Shear test with holes

- Material AA2050-T84
- Offset hole
- Primary crack through hole
- Secondary crack in homogeneously strained area



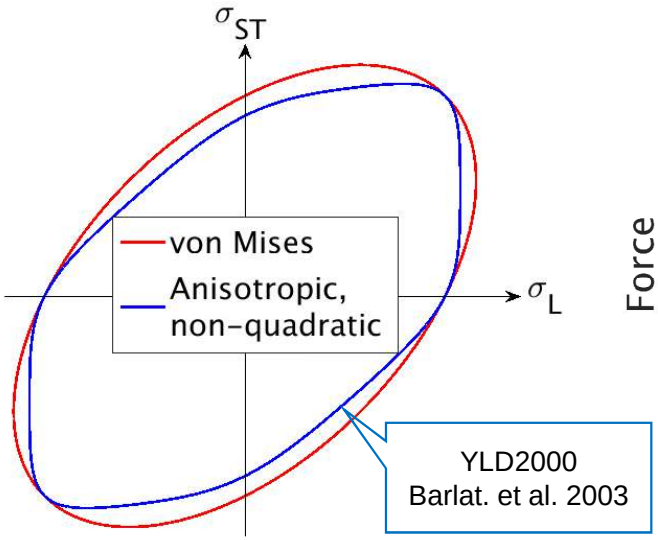
Shear test – finite element simulation

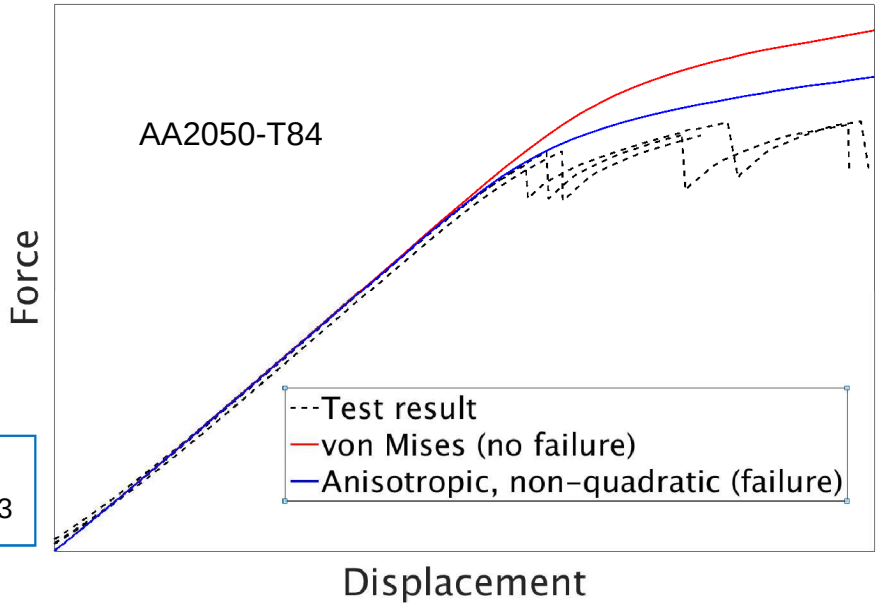
Strength anisotropy:

- Example: $R_{m,ST} \neq R_{m,L}$

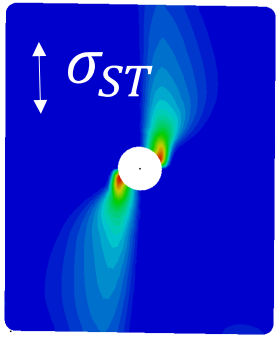
Relation between shear and normal strength

- Al-Li : $\frac{\sigma}{\tau} \approx 2$
- von Mises : $\frac{\sigma}{\tau} = \sqrt{3}$

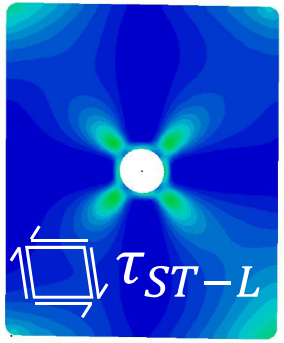




Normal stress



Shear stress



An accurate representation of the yield surface (anisotropy) is necessary to predict the force-displacement.

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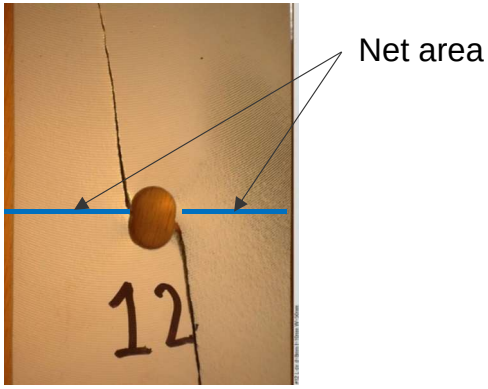
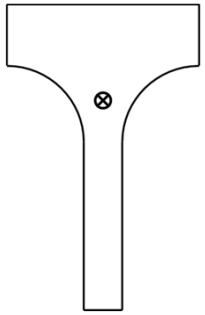
Analytical calculations

- Predictions of failure loads were made with classical analytical methods

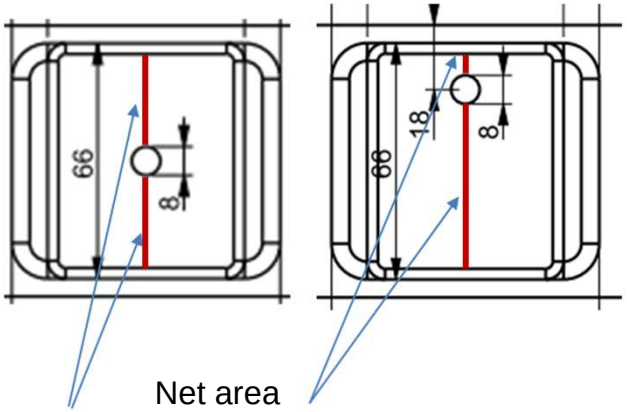
$F_{test} \approx R_m A_{net}$



$M_{test} > W_b R_m$



$F_{test} \approx 2R_{sm}\, A$



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Conclusions

- Fractures in AA7050-T7451 are in general perpendicular to the major principle stress
- Fractures in AA2050-T84 are prone to start or turn towards the L-direction
- The usual static sizing methods can be used
- Strength anisotropy must be accounted for in the sizing