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Modal nudging and elastic tailoring for blade stiffened wing structures

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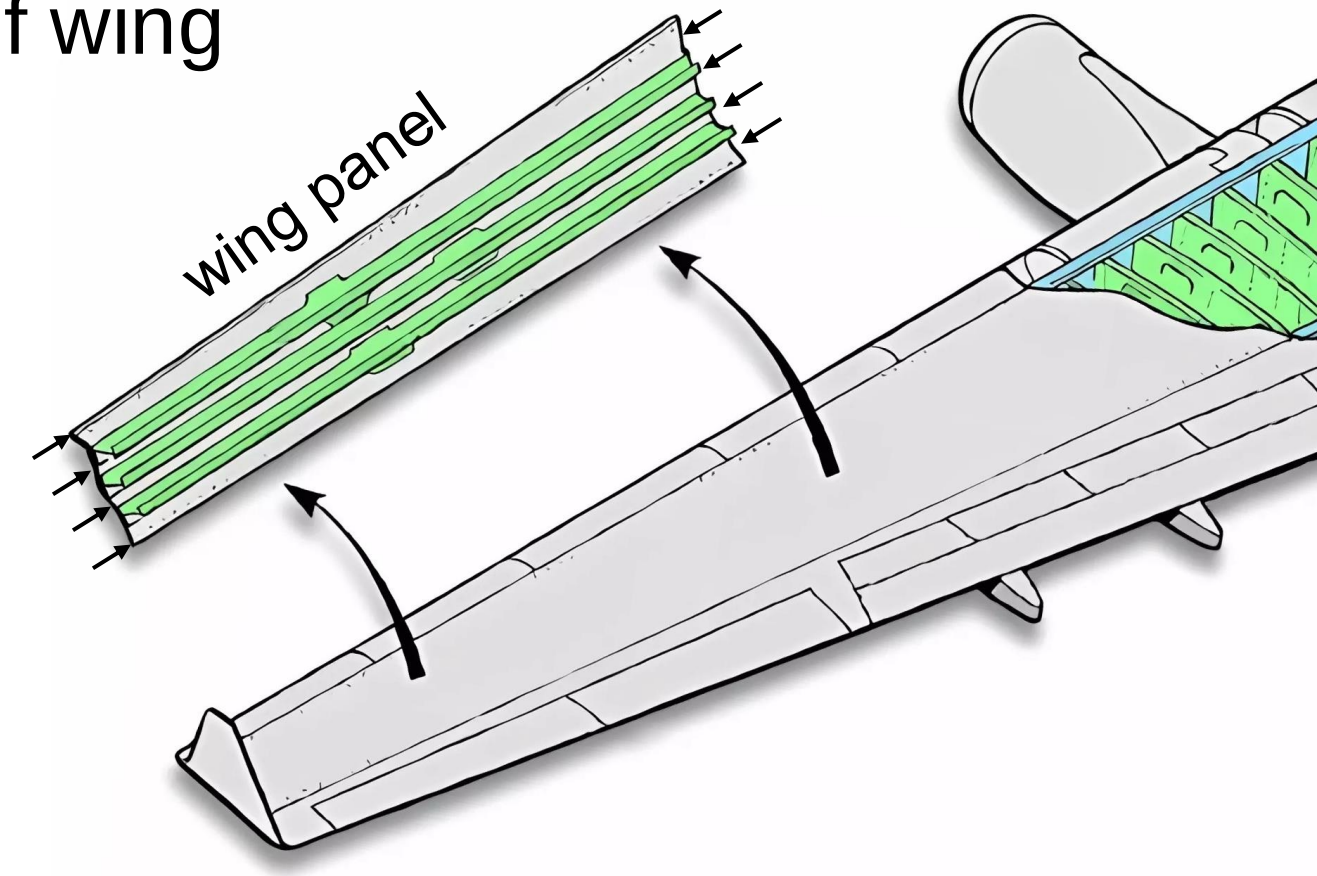
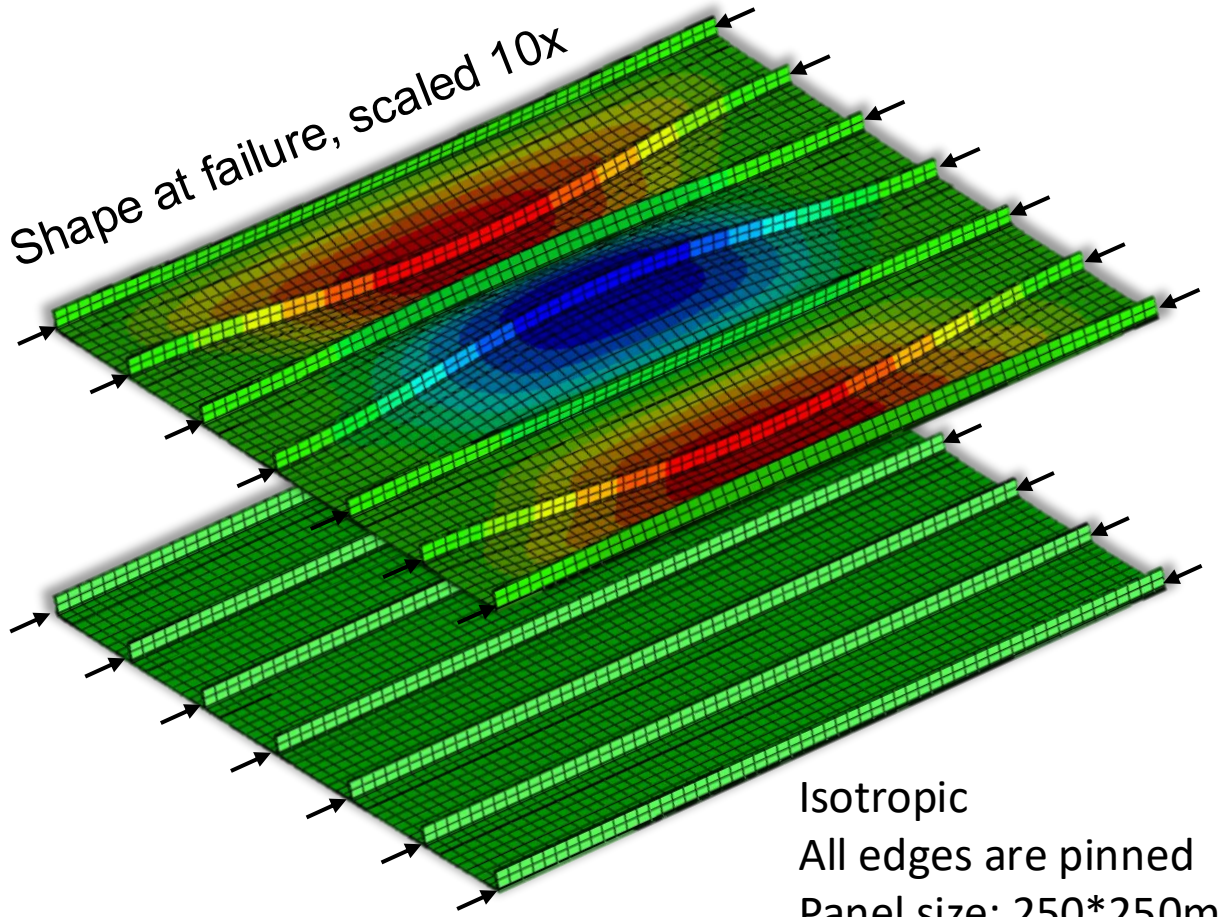
Background

- Wing: **40%** structural weight
- Wing panel: the largest part of wing
- Thin-walled structure
- -1kg = -25 tons CO_2 /lifetime



Example 1

- Variables
  - Panel thickness
  - Stringer thickness
  - Stringer height
  - No. stringers (maximum 7)
- Optimisation settings
  - Objective: lightweight
  - Constraints
    - Failure load > 30kN
    - No instability
    - von Mises stress < 280MPa
- Nonlinear analysis (ABAQUS Riks)

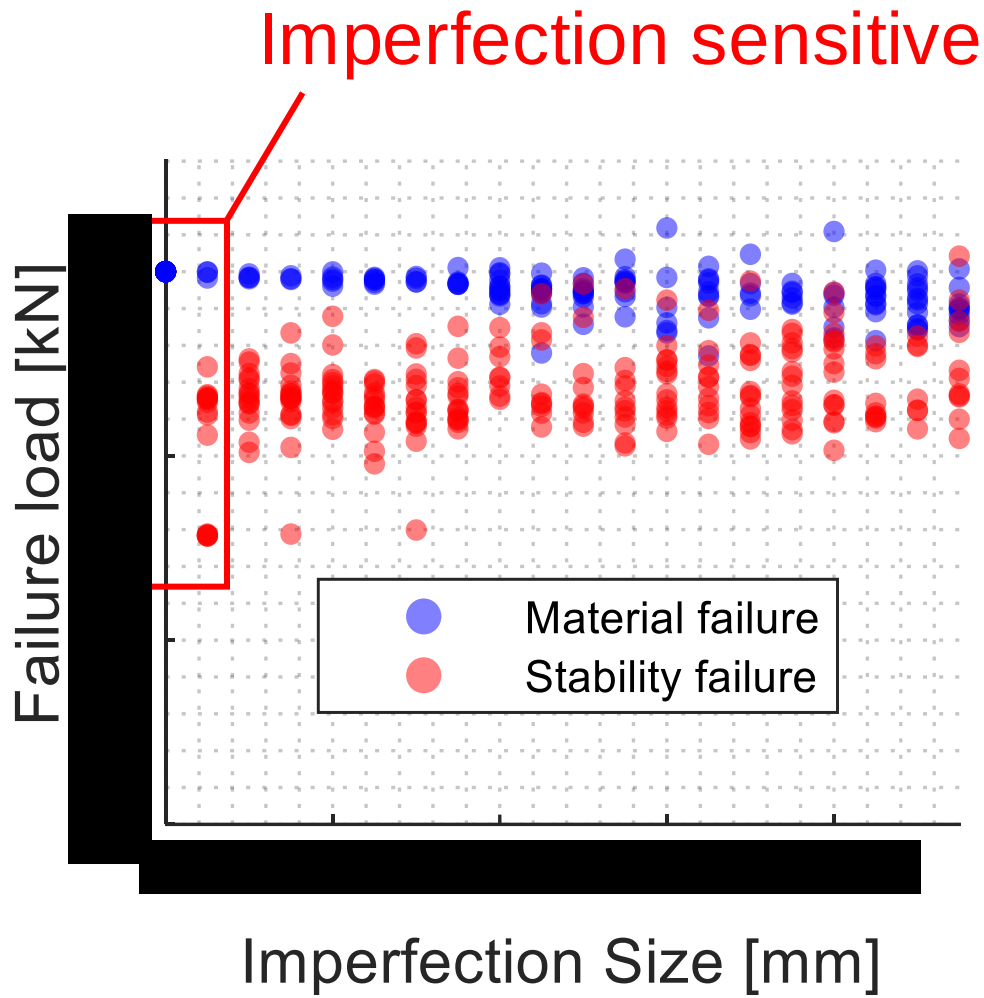


Isotropic
All edges are pinned
Panel size: 250*250mm

Globally optimised result

Example 1

- Imperfection sensitivity analysis
- Each dot is a nonlinear analysis



- An imperfection sensitive design

Design paradox

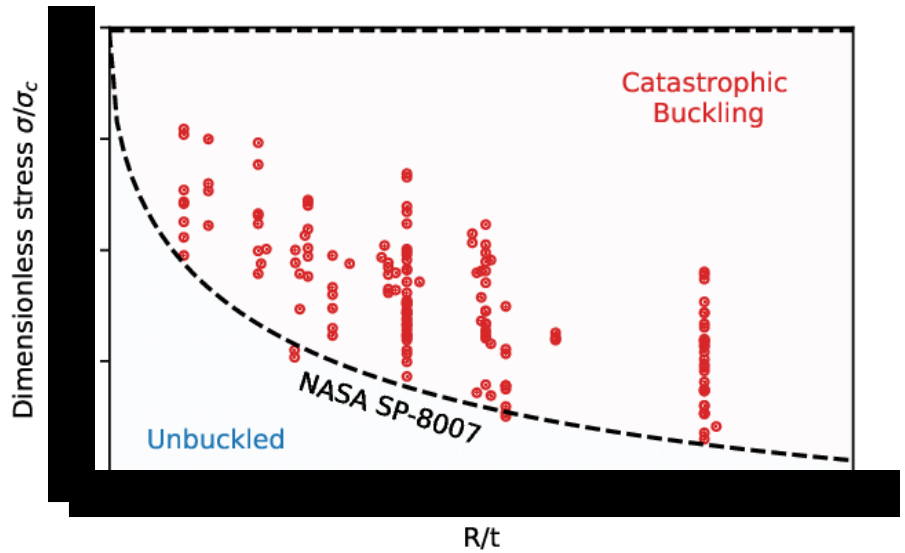
Weight reduction as objective

All failure modes happen at once

Imperfection sensitive design

Material capacity wasted

NASA's knock down factor

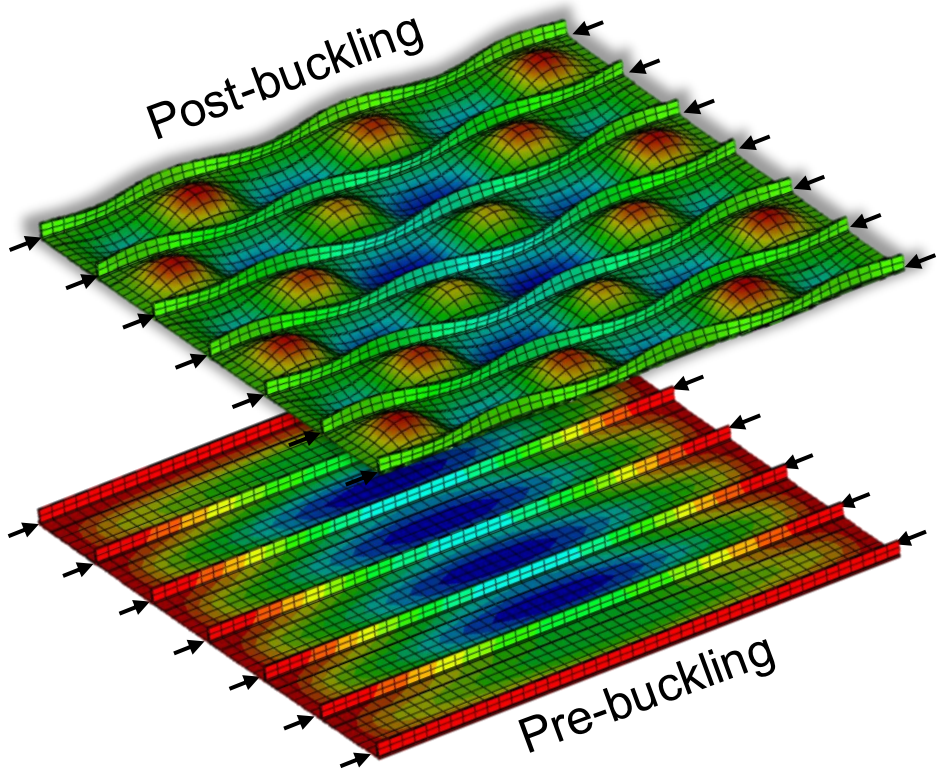


Paradigm shift

- Avoiding post-buckling → embracing post-buckling

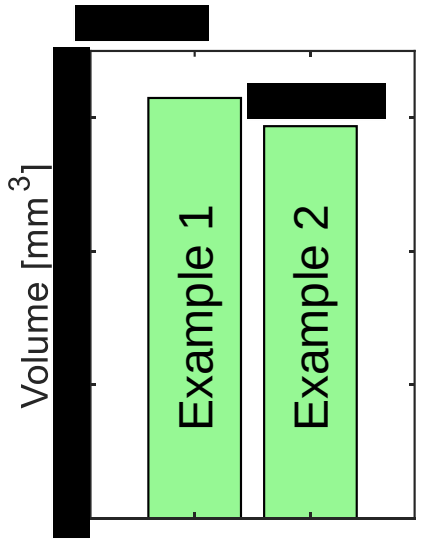
- Post-buckling ≠ structural failure

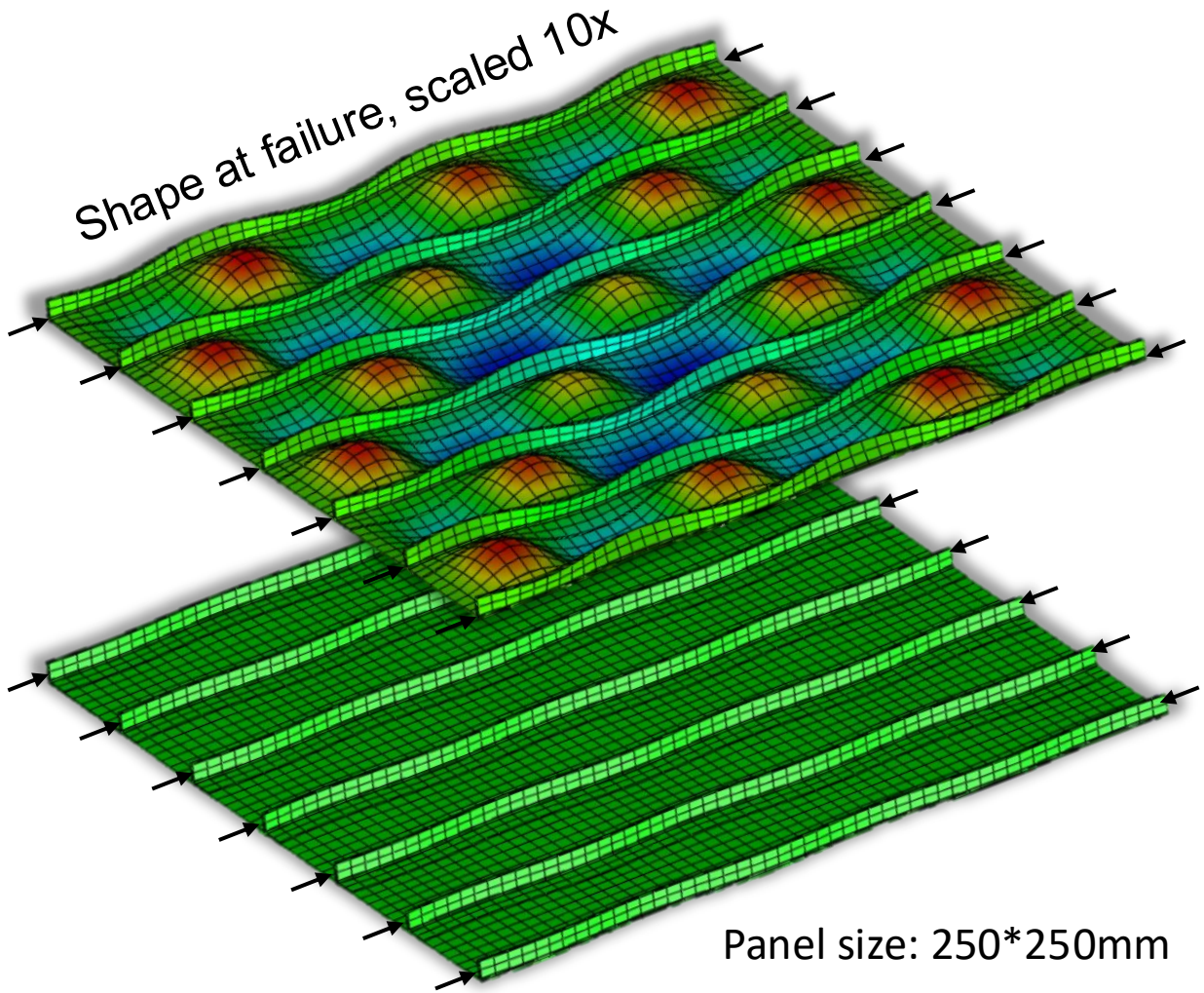
- Post-buckling as design space:
  - Reduce weight by 6.7%
  - Remove imperfection sensitivity



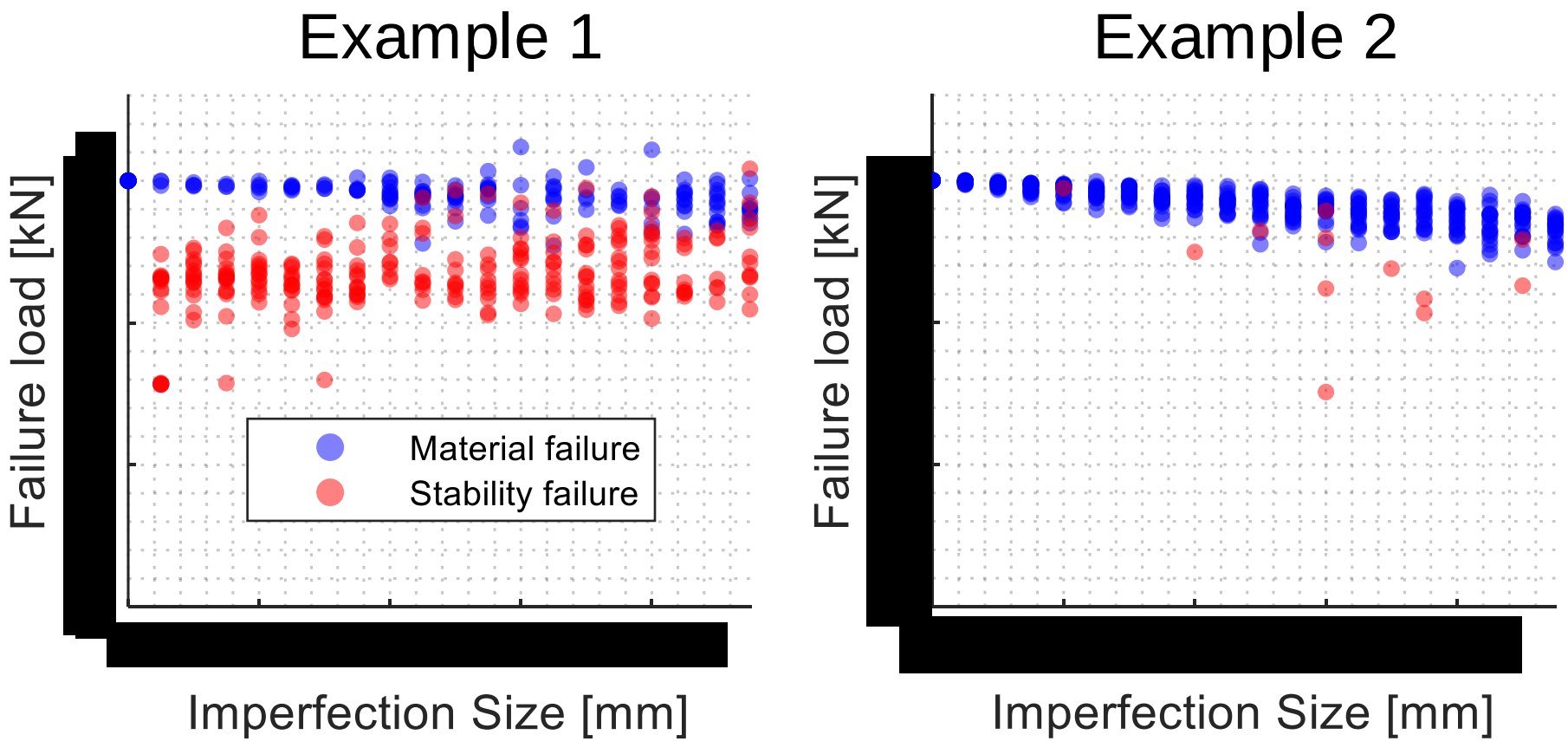
Example 2

- Identical optimisation settings
- Undulating stringers as a design feature





Imperfection sensitivity



Conclusions

- A method to reduce geometric imperfection sensitivity by using undulating stringers
- Maintains smooth aerodynamic profile
- 6.7% weight reduction for the same target load

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Thank you!

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