Institut für Strukturmechanik und Leichtbau

RWTH AACHEN UNIVERSITY

Advanced Sizing Strategies for Preliminary Design of Orthotropic Grid Stiffened Shell Structures

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25.03.2015

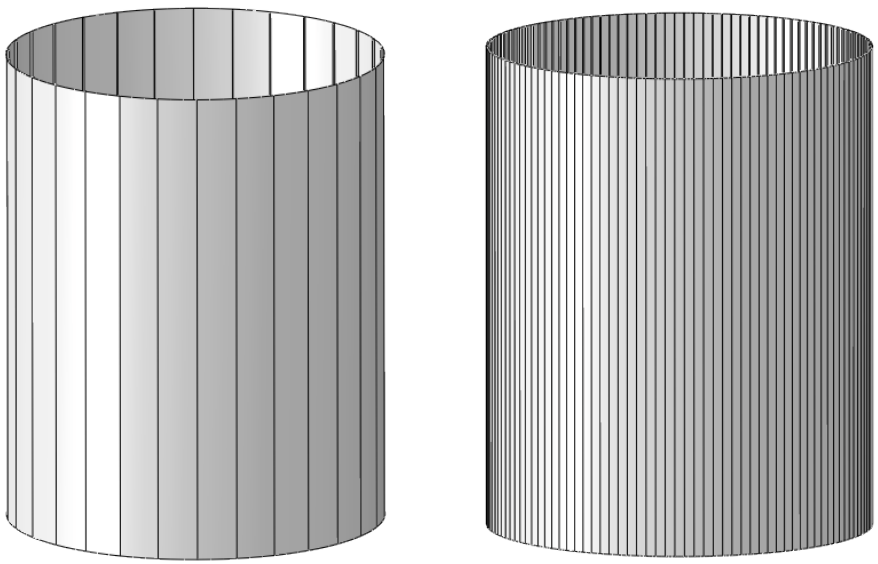
Integration in DESICOS project

- Objective of WP3:
  - → development of new design approaches
- Our study structures:
  - → stiffened aluminium shells (with TU Delft)
- Two challenges when designing stiffened shells:

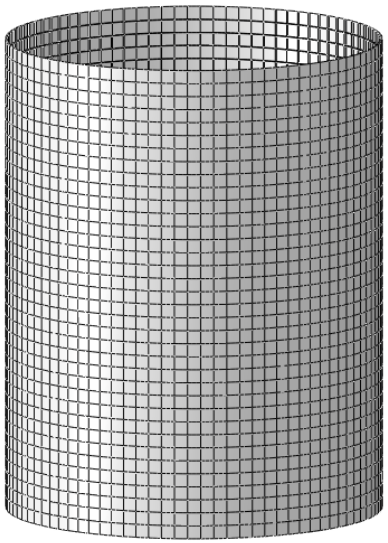
1. taking imperfections into account using the SPLA
   - → key questions:
     1. same characteristics as for unstiffened shells?
     2. more or less conservative design compared to emp. KDF?
2. deriving a suitable stiffening pattern by developing a sizing strategy

SPLA
Overview stiffened shell

- Dimensions acc. to a DESICOS test structure:
  → R= 400 mm, L=1000 mm
- Stiffened shell structures studied:



→ n_{Str}=**30**, 45, 90, **126**

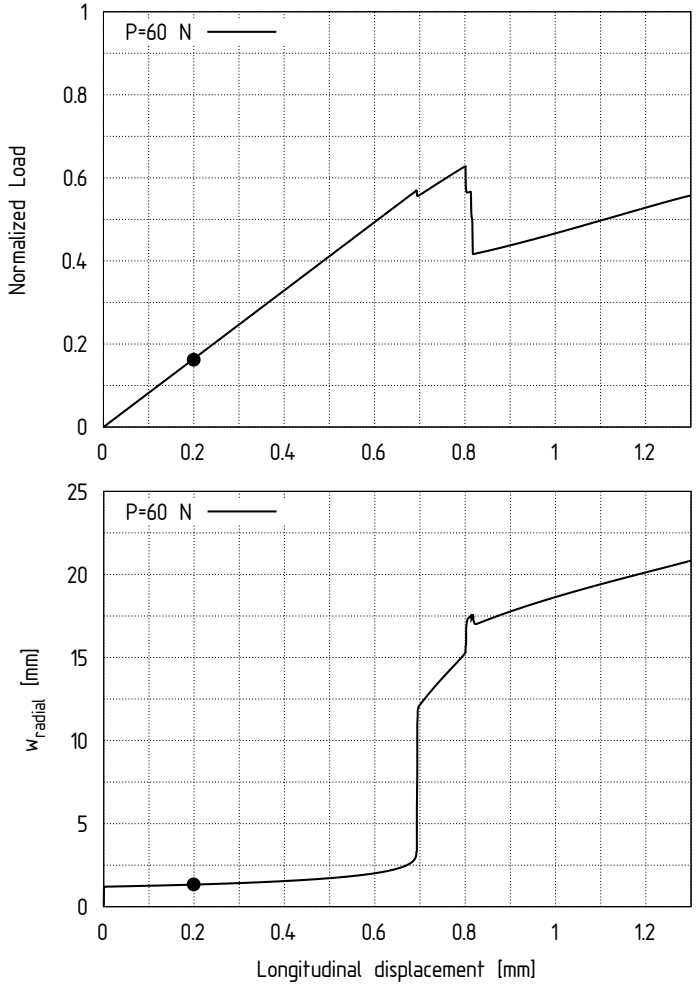


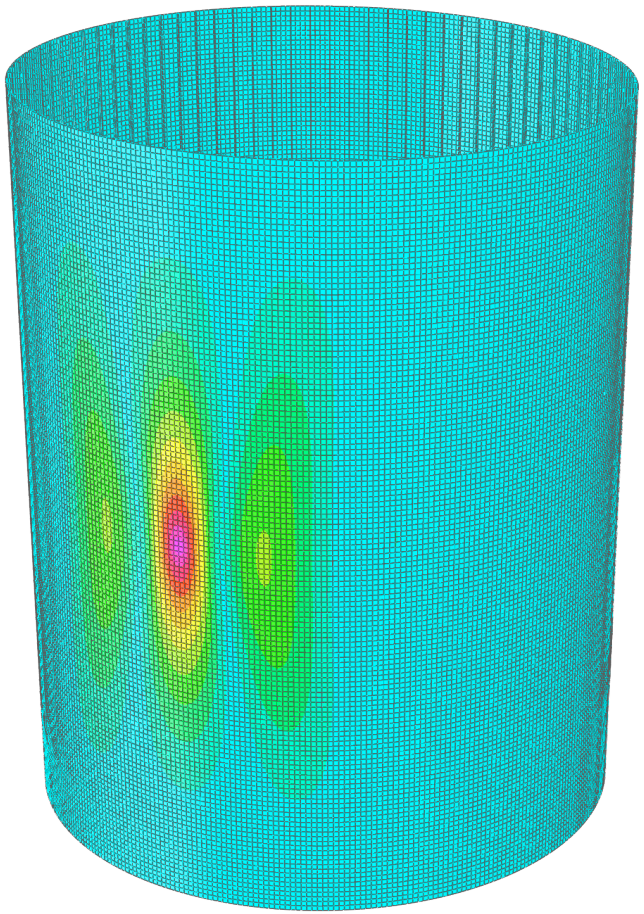
→ n_{Str}=90, n_R=36

SPLA
Numerical modelling

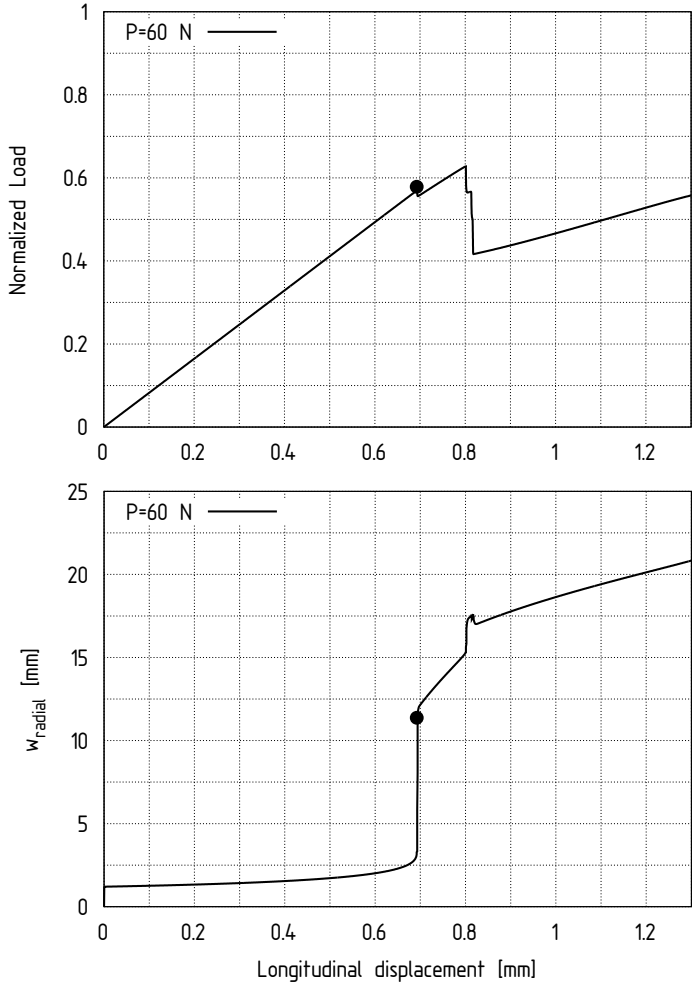
- FE-models:
  - → discrete/detailed finite element models
  - → smeared models
- Variation of point of SPL introduction
  - → at a stiffener
  - → between stiffeners

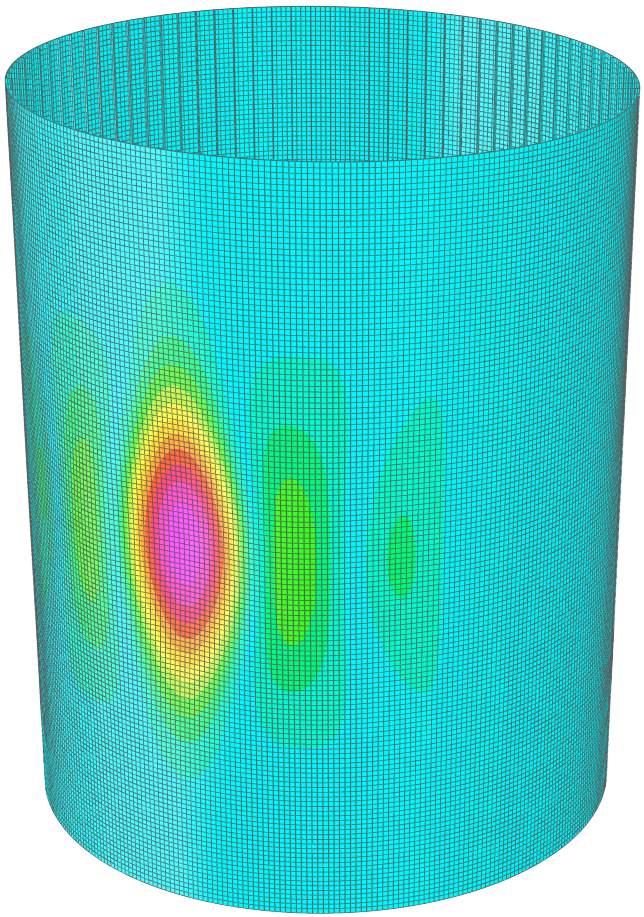
SPLA - results
Pre-buckling regime



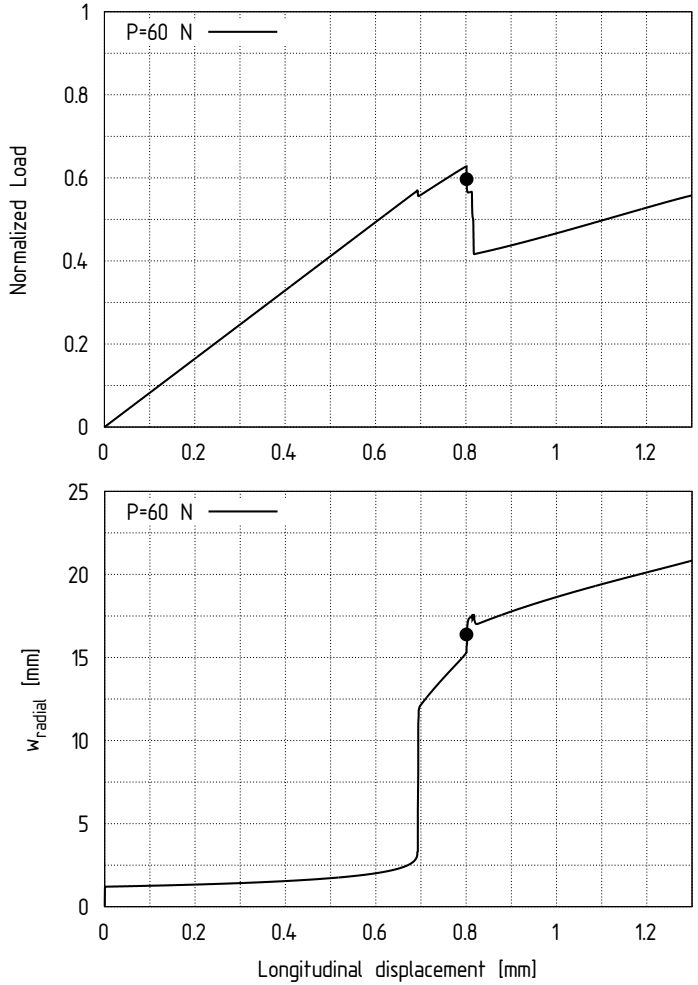


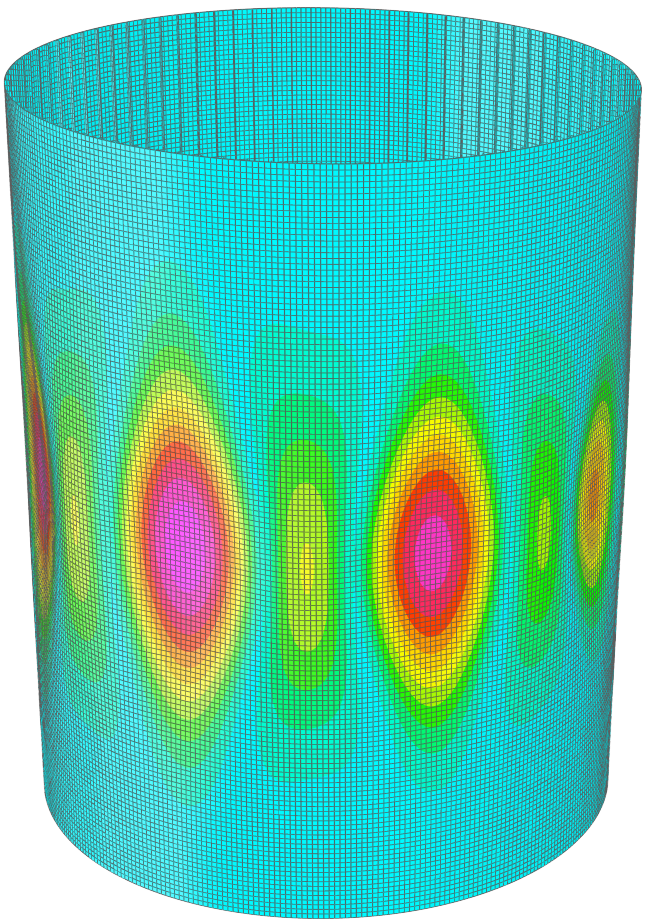
SPLA - results
Local snap-through



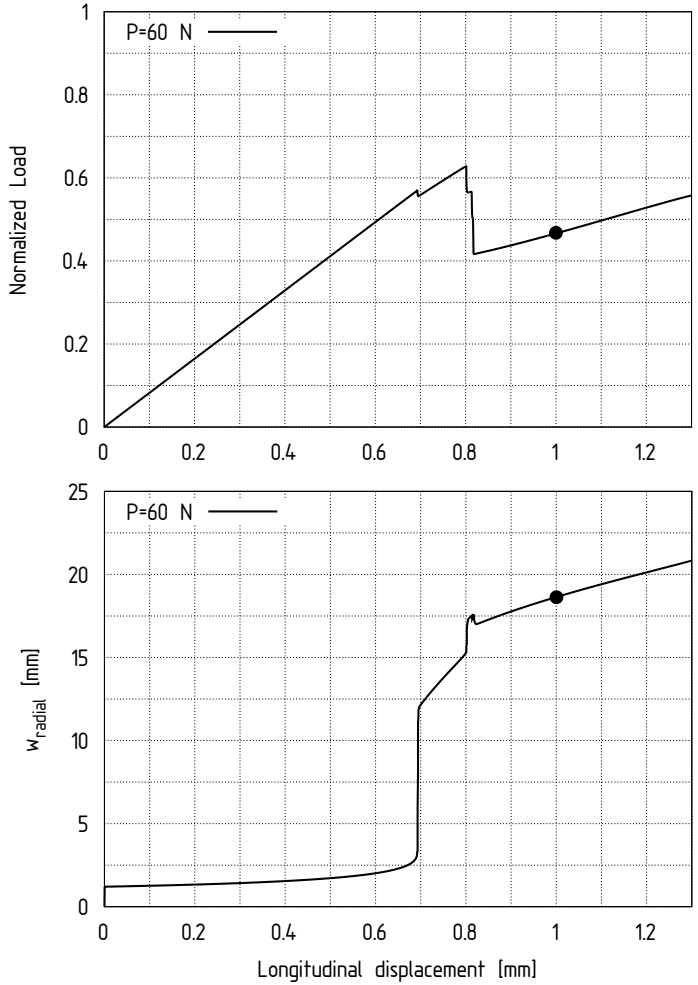


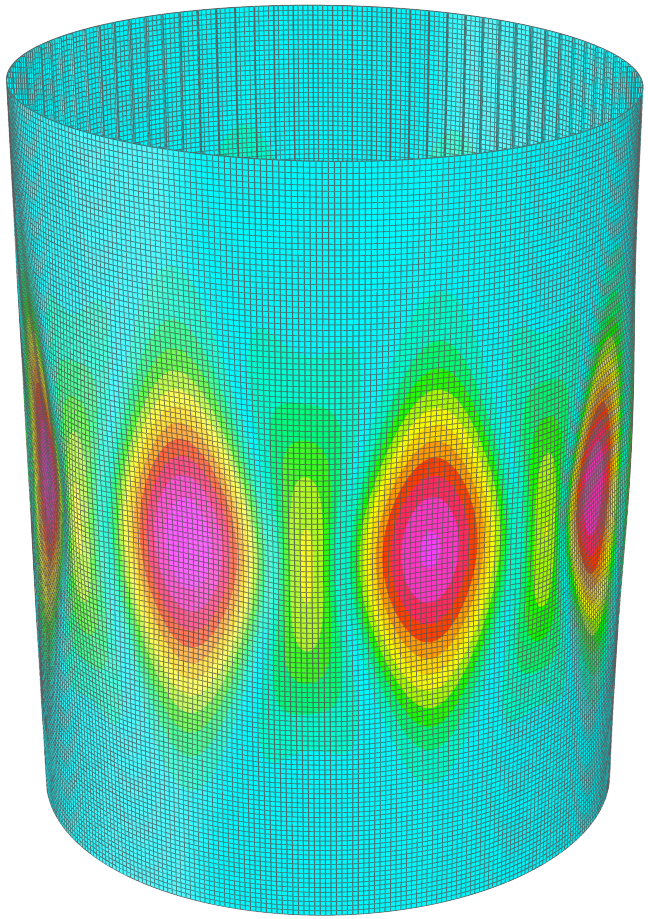
SPLA - results
Global collapse





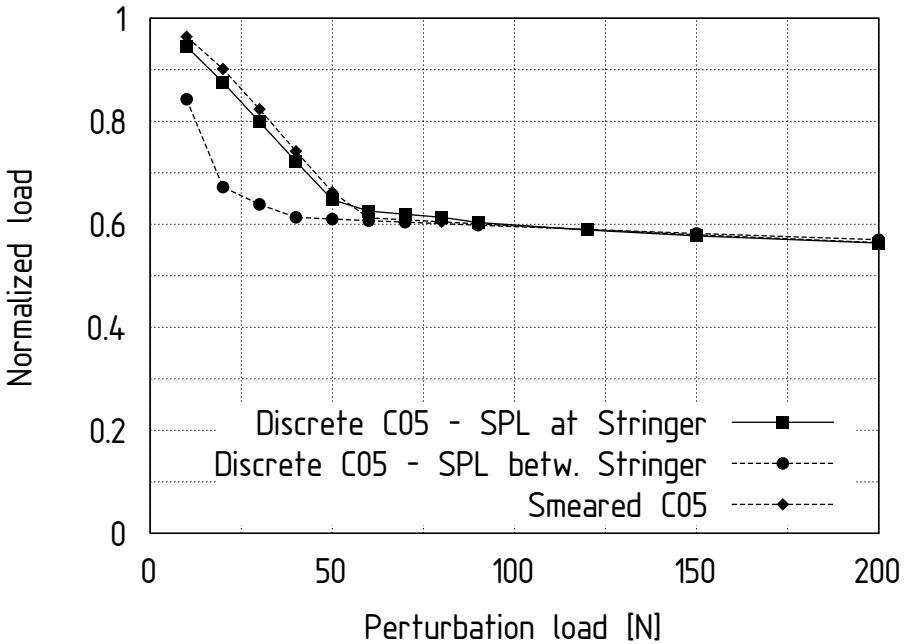
SPLA - results
Post-buckling regime





SPLA - results
Comp. to emp. KDF

- Stringer stiffened shells
- Normalized design load SPLA:
  → 0.613
- Emp. knock down factor Almroth $\rho_{90\%}$:
  → 0.626

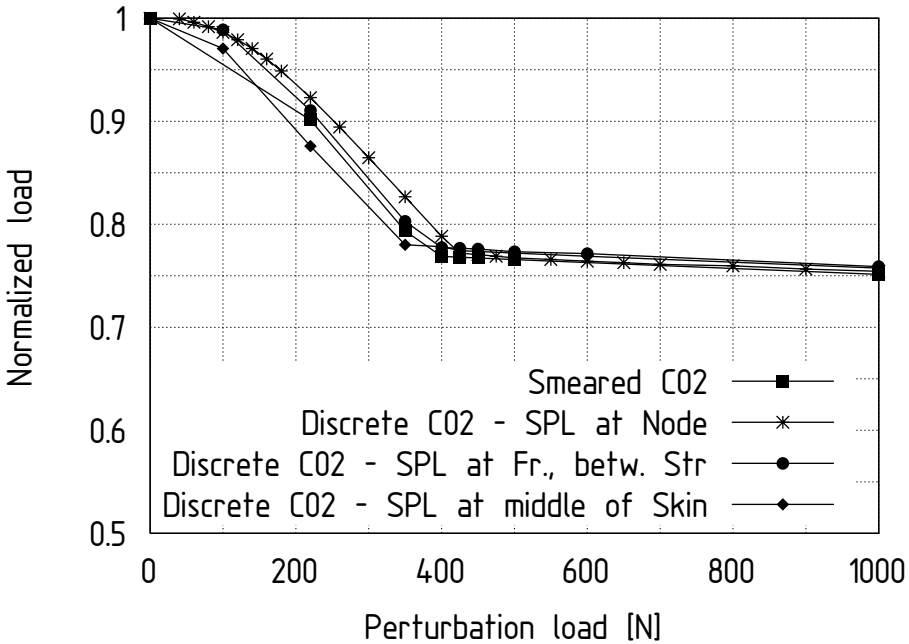


SPLA - results
Comp. to emp. KDF

- Orthogrid stiffened shells

- Normalized design load SPLA:
  → 0.772

- Emp. knock down factor Almroth $\rho_{90\%}$:
  → 0.745

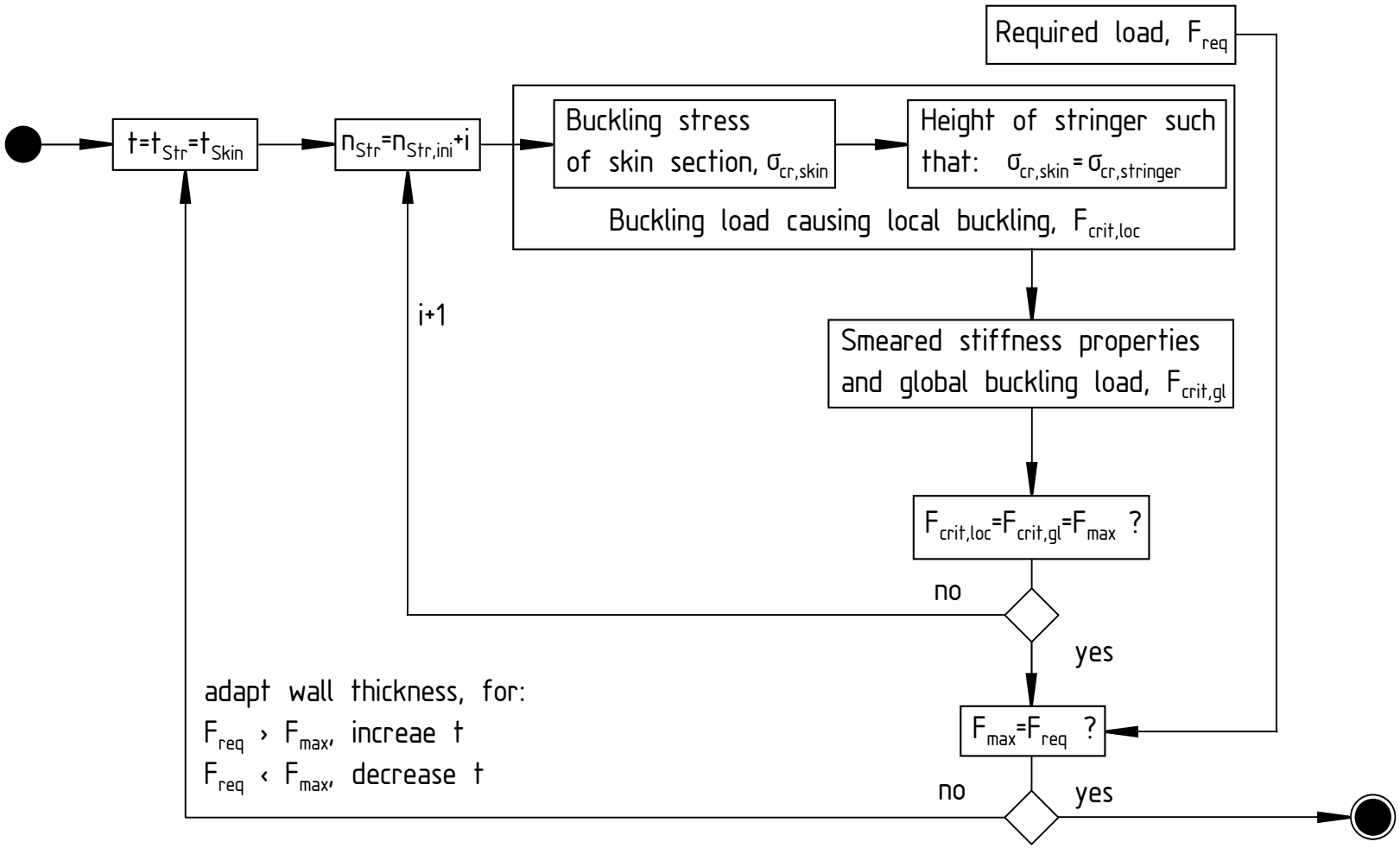


- **Summary:** SPLA design loads were similar to the results obtained using Almroth's $\rho_{90\%}$ empirical KDF

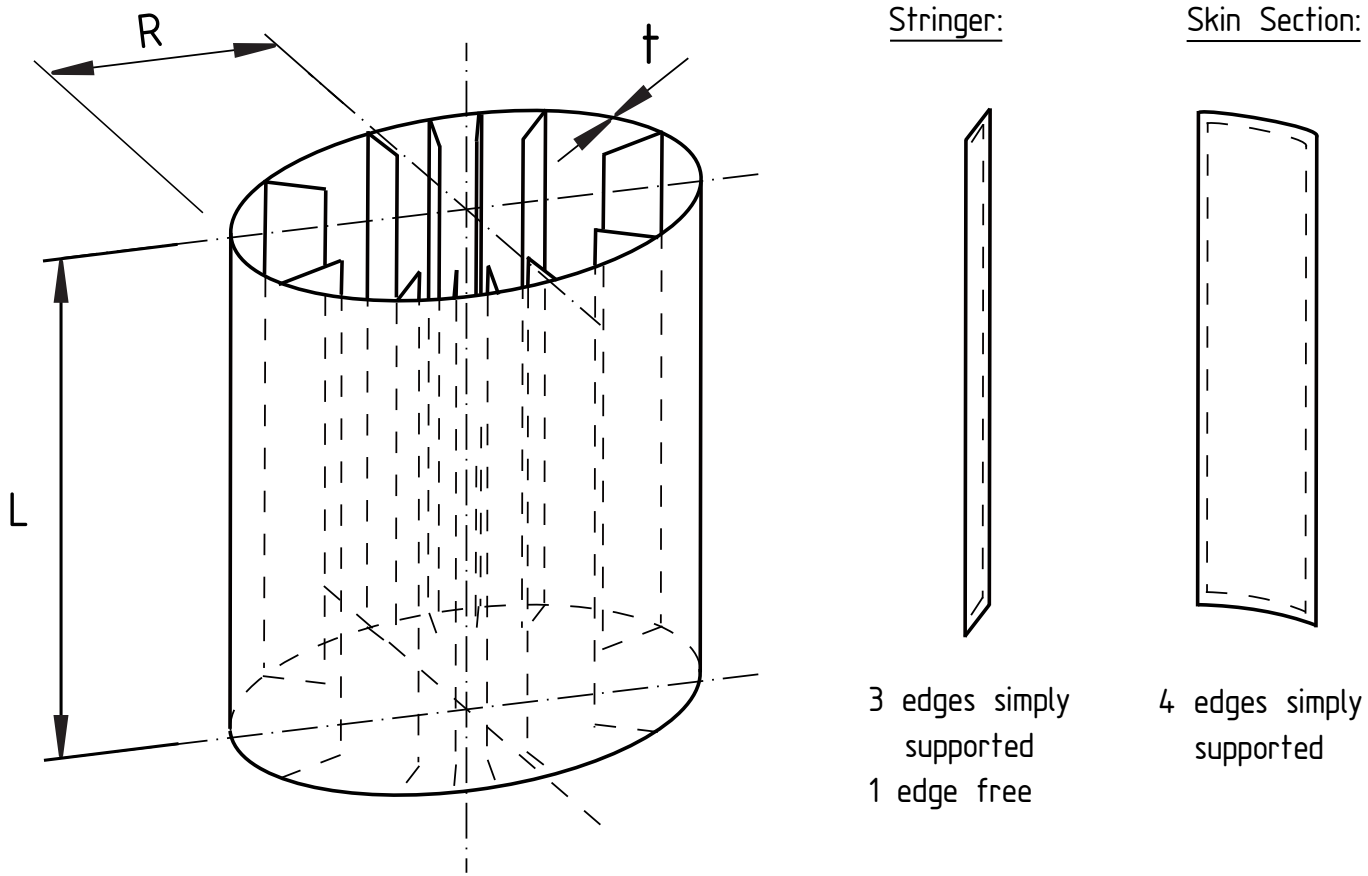
Sizing strategy
General idea

- Buckling modes:
  - → local buckling skin sections
  - → local buckling stringers
  - → global buckling
- All failure modes occur at the same load
  - → as suggested in the isogrid design handbook
- Stiffener height is determined such that it buckles locally at the same stress as the skin section
  - → constant relation between stiffener height and stiffener spacing
  - → number of stringers as initial variable

Sizing strategy
Procedure



Sizing strategy
Structural models

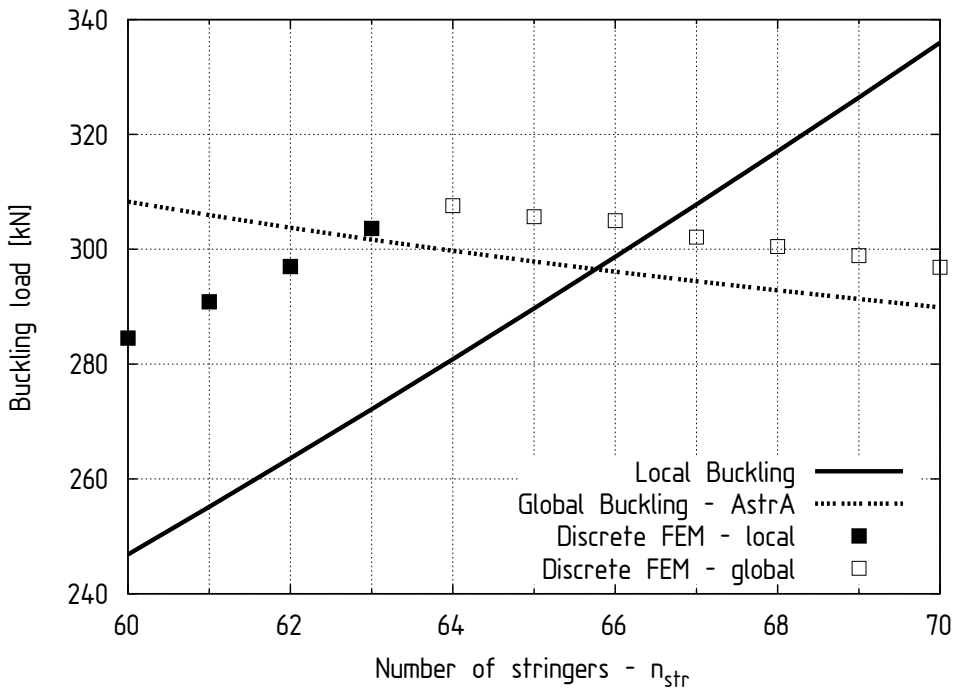


→ local buckling: analytical methods - buckling of plates

→ global buckling: AstrA / Tennyson

Sizing strategy
Stringer stiffened shell

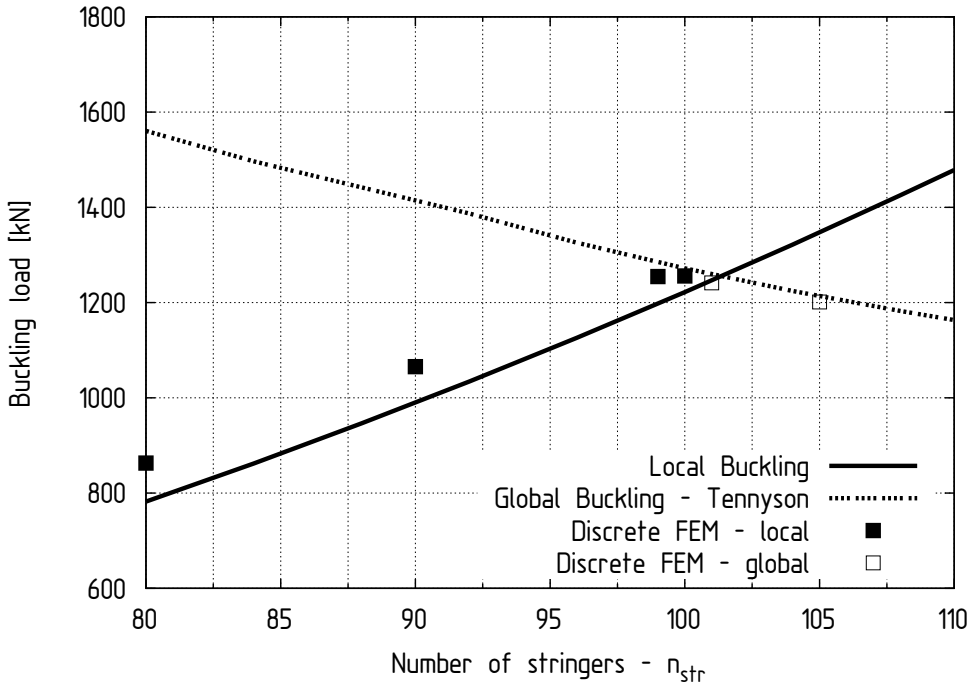
- Buckling load vs. number of stringers



→ good agreement betw. discrete FEM and analytical methods

Sizing strategy
Orthogrid stiffened shell

- Buckling load vs. number of stringers

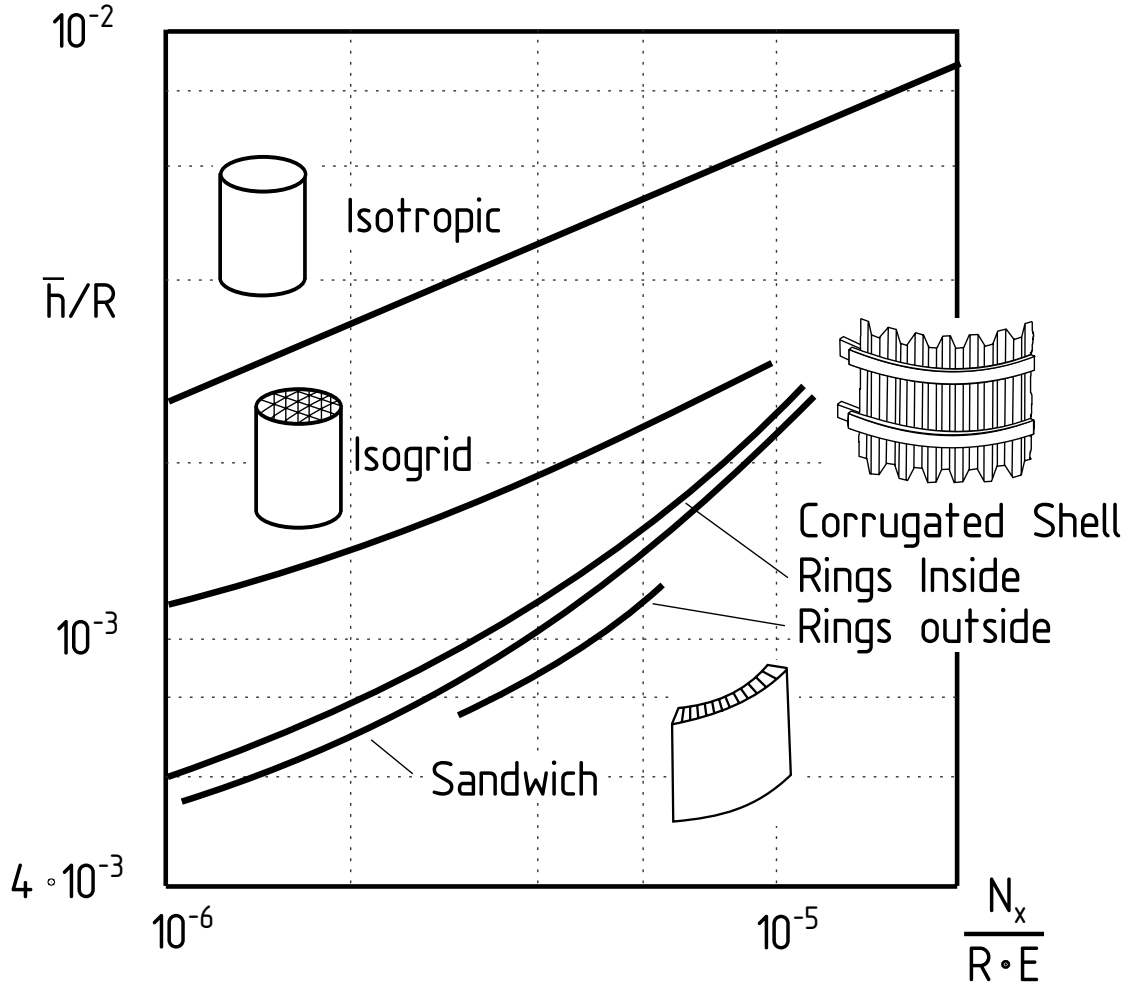


→ good agreement betw. discrete FEM and analytical methods

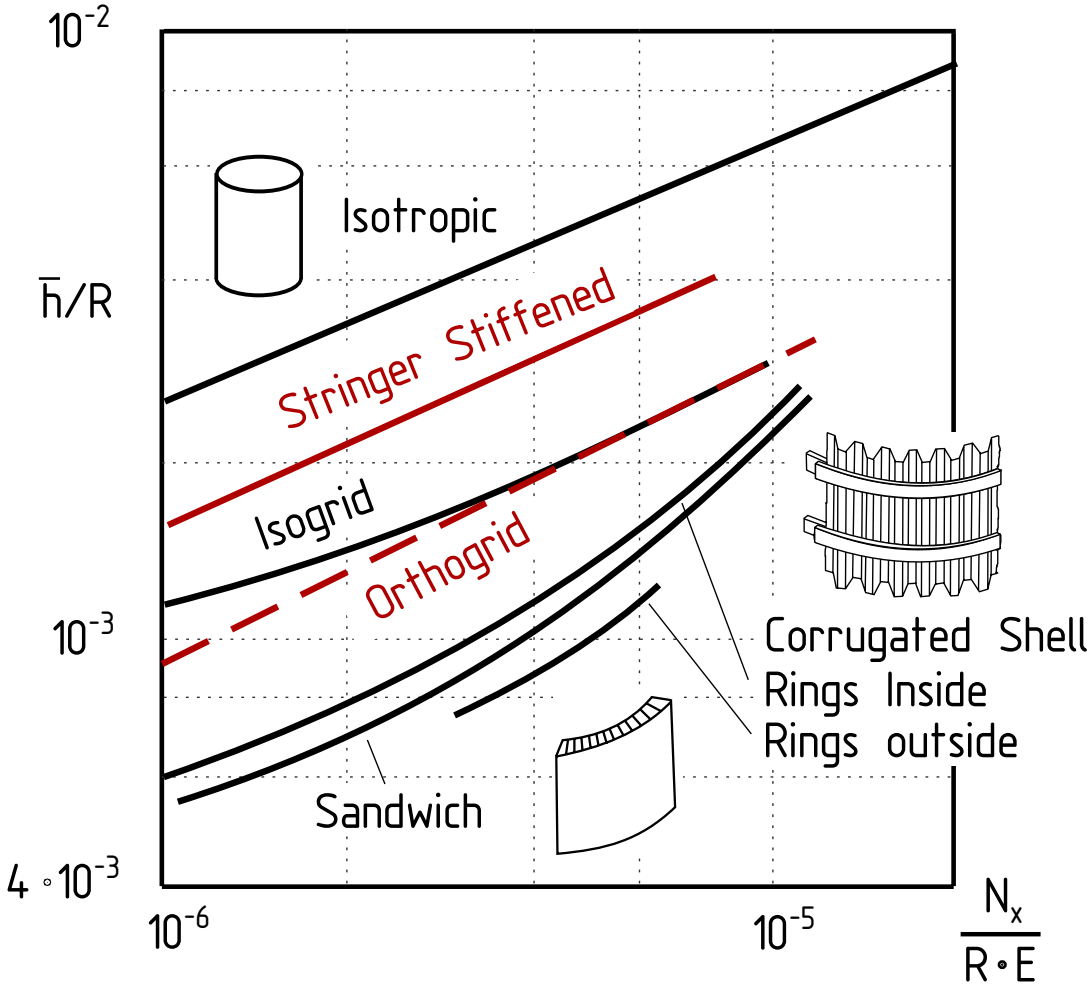
Sizing strategy
Summary

- The sizing process presented in conjunction with the structural models chosen allows:
  - → deriving initial configurations
  - → for stringer stiffened and orthogrid stiffened shells
  - → in the case of a axial compressive forces
- Manufacturing restraints are currently not considered
- Drawbacks due to current structural models:
  - → combined loading and inner pressure can recently not be taken into account
  - → composite materials can recently not be taken into account

Weight strength curves



Weight strength curves



Summary and conclusion

- SPLA applied to stiffened shells led to similar results than using empirical knock down factors
- The sizing approach allows to derive preliminary design efficiently
  - → mathematical optimization algorithms are not needed
  - → the configurations derived can be considered as starting point for detailed design of stiffened shells
- The general idea of the sizing approach can also be implemented using numerical structural models
  - → deriving weight strength curves for pressurized cylinders and composite stringer and orthogrid stiffened shells.

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Thank you for your attention!

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