ACHIEVEMENTS IN THE BUCKLING OF THIN-WALLED COMPOSITE LAUNCHER STRUCTURES

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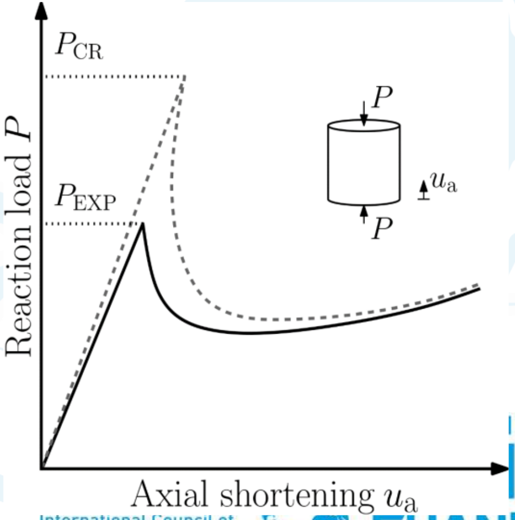
Motivation

- Space industry strives for significantly reduced development and operating costs.
- Possibility 1: Reduction of structural weight by higher content on composites.
- Possibility 2: The use reliable simulation methods to minimize expensive and time-consuming experimental design studies.

Motivation

- For most structural parts of real launcher structures buckling is the critical design criterion.
- Due to the high imperfection sensitivity of unstiffened cylindrical shells it is still today a challenge to predict a reliable buckling load.

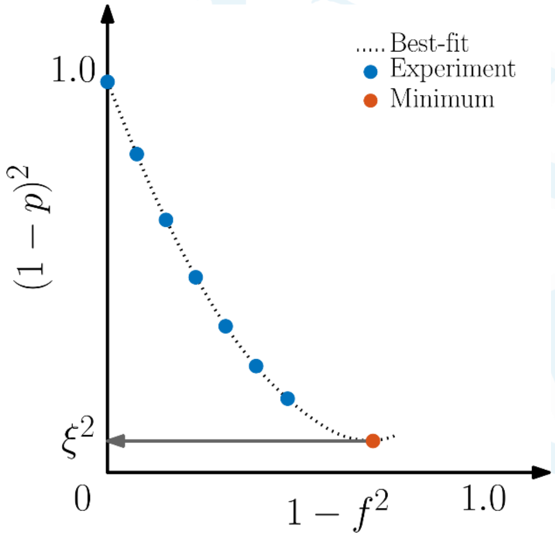


Vibration Correlation Technique (VCT)

- Allows a non-destructive prediction of the buckling load in the experiment.
- It is based on the relation that the eigenfrequency becomes smaller under the increase of the axial compression and in the case of the bucking the eigenfrequency is zero.
- For beams the relationship is linear.
- For shells the relation is due to the imperfection sensitivity nonlinear.

Vibration Correlation Technique (VCT)

- In 2014, Arbelo developed an improved empirical VCT formulation of cylindrical shells.
- The buckling load is calculated using $P_{VCT} = P_{CR}(1-\xi)$.
- In 2019, Franzoni verified analytically this approach.



- f is the ratio between the natural frequency of the loaded structure and the natural frequency of the unloaded structure.
- p is the ratio between the axial load and the critical buckling load P_{CR}.

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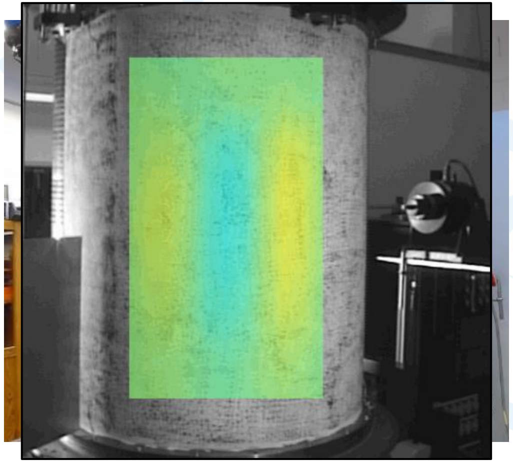
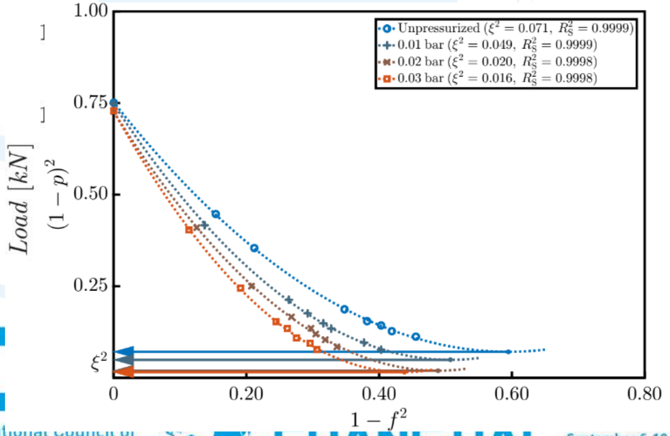
Example 1 - Metallic cylinder axially loaded with internal pressure

- Simplified downscaled model of a launcher propellant tank.
- The VCT estimations presented a good correlation when compared to their respective experimental result for the buckling load.
- The deviations are within 4.0% and 10.0% on the conservative side.





Example 2 - Buckling tests with VCT measurement with the same samples at different test facilities

- A composite cylindrical shell was tested at DLR and afterwards at TU Delft.
- There was 22% deviation among the buckling loads

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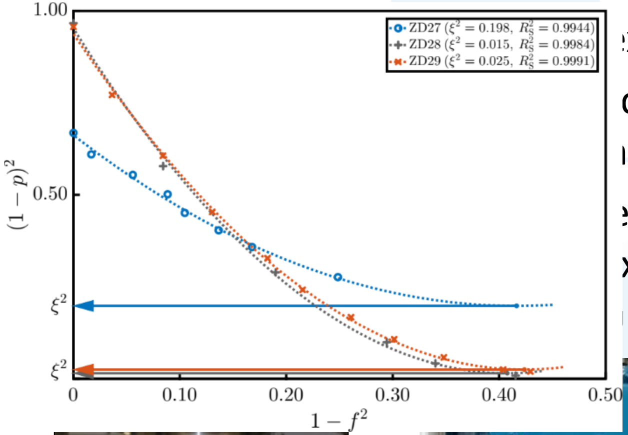
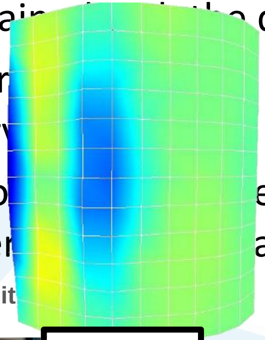
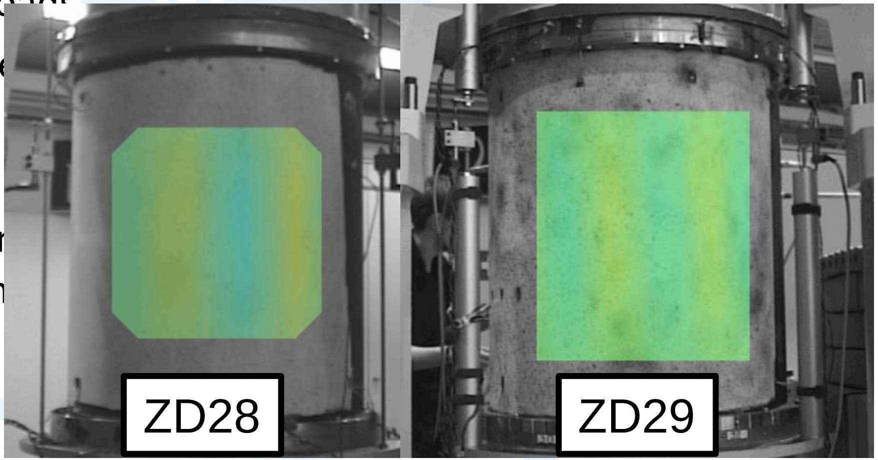
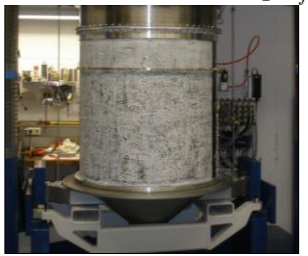


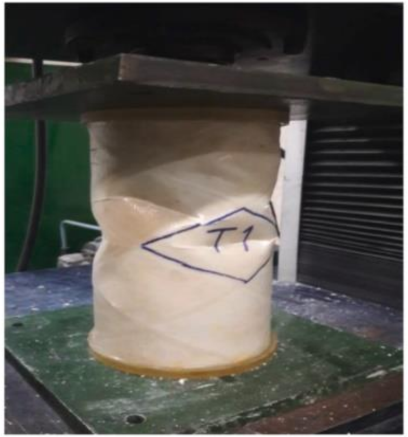


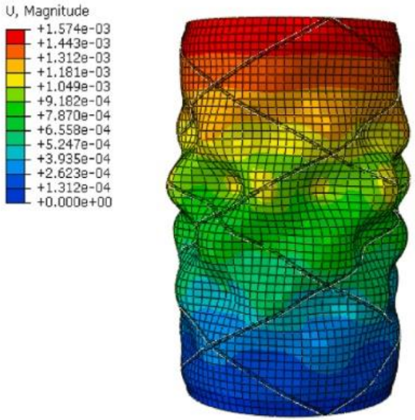




Example 3 - Composite lattice sandwich cylinder under axial compression

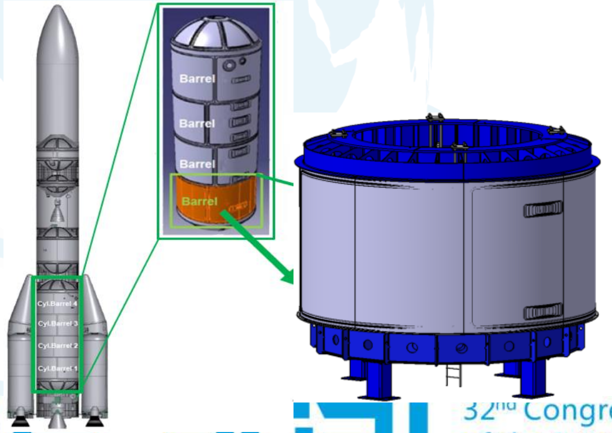
- 4 axially loaded composite lattice sandwich cylinders were tested verifying the VCT approach.
- The maximum difference between the VCT estimated buckling load and the experimental buckling load is less than 5%.





Example 4 - VCT test for the Ariane 6 LH2 section under combined loading

- The structure was loaded by axial compression and bending.
- During the buckling test a VCT measurement was performed in parallel.
- It was the first time, that VCT was applied to a real space structure.
- The VCT prediction was very good.

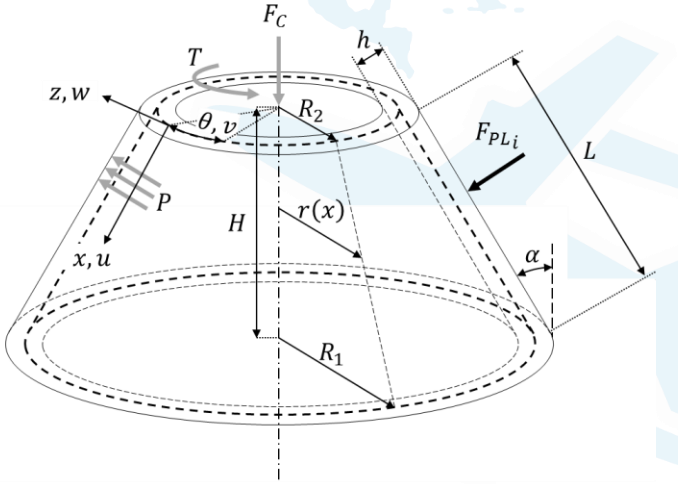


Fast Design Method by Ritz-approach

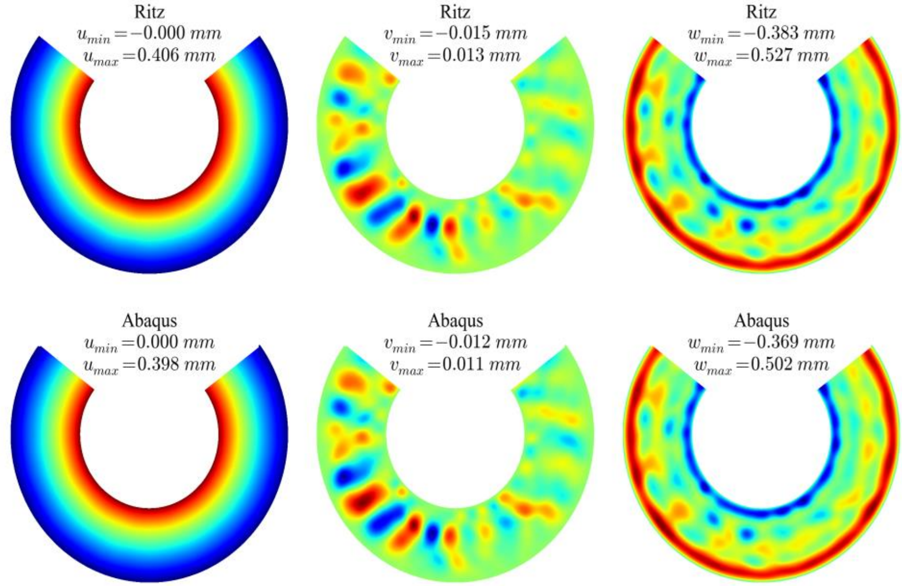
- A fast semi-analytical method based on the Ritz-approach.
- Predicts the static and the instability of the non-linear buckling.
- Unstiffened and stiffened laminated composite cones and cylinders.
- Various loads and boundary conditions is used.
- Considers geometric and load imperfections.

Example 5 - Fast simulation of conical composite structures

- Imperfect composite conical structure under axial compression, torsion and pressure.
- Comparison of the deformations obtained by the semi-analytical Ritz-approach and FEM (Abaqus).
- Arbitrary boundary conditions

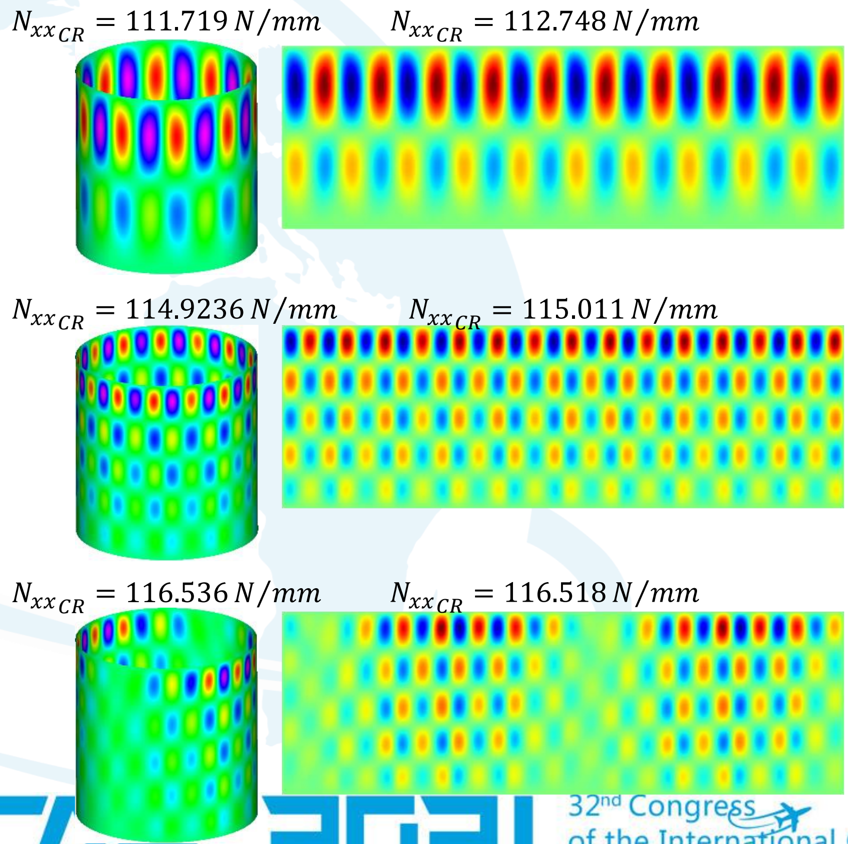


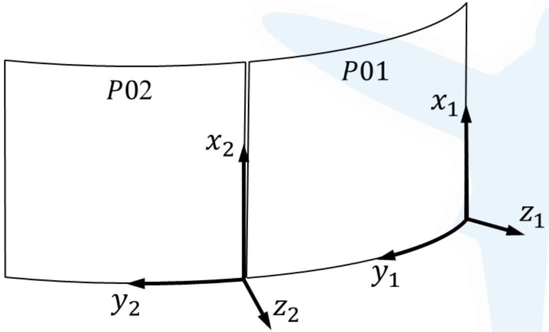
Single-domain model



Example 6 - Fast simulation of stiffened shells

- The approach assembles cylindrical shell and plate domains modeling skin and stringers.
- Combines efficiency of analytical integration with flexibility of multi-domain approaches.
- Accurate calculation of strain, stresses, modal behaviour and buckling loads.





Multi-domain model