11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

MODAL INTERACTION CHARACTERISTICS OF AN AXIALLY LOADED COMPOSITE CYLINDRICAL SHELL USING KOITER'S IMPERFECTION SENSITIVITY ANALYSIS

Eelco Jansen and Raimund Rolfes

Leibniz Universität Hannover, Institute of Structural Analysis
Appelstr. 9A, 30167 Hannover, Germany, www.isd.uni-hannover.de
* Corresponding author: e.jansen@isd.uni-hannover.de

Key Words: *Structural Design, Buckling, Stability, Thin-walled Structures, Composite Structures.*

Thin-walled cylindrical shells are used as main structural components in various branches of engineering. Buckling is the key design criterion for these thin-walled structures. Cylindrical shells typically exhibit unstable post-buckling behavior and their behavior is correspondingly very sensitive to small geometric or load imperfections.In this paper, an approach to assess the modal interaction characteristics of composite cylinders under axial loading and their effects on the load carrying capability is presented.

In recent years, extensive research, including the NASA Shell Buckling Knock-Down Factor (SBKDF) project, has been carried out in order to develop design approaches that lead to appropriate, not too conservative design loads [1-4]. Both deterministic and probabilistic approaches are under investigation within the EU FP7 project DESICOS. An important deterministic approach further pursued within DESICOS is the Single Perturbation Load Approach.

An alternative deterministic approach to define knock down factors is based on Koiter's imperfection sensitivity theory. This theory has been applied to the buckling of composite shells both within a semi-analytical context [5] and within a Finite Element framework [6]. In [5], Koiter's initial postbuckling theory was employed using a numerical solution of the governing Donnell-type differential equations, while in [6] a Finite Element based reduced order model with a small number of representative modes was used. In [6] it was shown that for a given imperfection pattern, for small imperfection amplitudes the limit-point buckling loads obtained with the reduced order model compare reasonably well with full model nonlinear analysis. The objective of the present work is to investigate the characteristics of specific relevant modal interactions and to determine how these interactions affect the decrease of the load carrying capability of composite shells.

In the present work, studies using both the semi-analytical and the Finite Element implementation of Koiter's theory are carried out in order to identify relevant modal interactions for composite shells under axial loading. Using representative imperfection patterns, both modes affine to buckling modes and appropriate specific modes, for certain composite shells the reduction of the load carrying capacity is established.

REFERENCES

[1] C. Hühne, R. Rolfes, E. Breitbach and J. Teßmer, "Robust design of composite cylindrical shells under axial compression - simulation and validation," Thin-Walled Structures, vol. 46, pp. 947-962, 2008.

[2] R. Degenhardt, A. Kling, A. Bethge, J. Orf, L. Kärger, K. Rohwer, R. Zimmermann, A. Calvi, "Investigations of imperfection sensitivity of unstiffened CFRP cylindrical shells", Composite Structures, Vol. 92 (8), pp. 1939-1946, 2010.

[3] B. Kriegesmann, M. Hilburger, and R. Rolfes, "The Effects of Geometric and Loading Imperfections on the Response and Lower-Bound Buckling Load of a Compression-Loaded Cylindrical Shell," 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference 20th AIAA/ASME/AHS Adaptive Structures Conference 14th AIAA, pp. 1-10, Apr. 2012.

[4] W. T. Haynie and M. W. Hilburger, "Comparison of Methods to Predict Lower Bound Buckling Loads of Cylinders under Axial Compression," in 51st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, p. 22, 2010.

[5] J. Arbocz and J.M.A.M. Hol, "Koiter's stability theory in a computeraided engineering (CAE) environment", Int. J. Solids Struct., 26(9/10), pp. 945– 973, 1990.

[6] T. Rahman and E. L. Jansen, "Finite element based coupled mode initial post-buckling analysis of a composite cylindrical shell," Thin-Walled Structures, vol. 48, pp. 25-32, Jan. 2010.