LARGE ELASTIC DEFORMATIONS OF LAMINATED CYLINDRICAL PANELS UNDER POINT LOAD

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1. Problem statement

A series of deep cylindrical laminated panels (Fig. 1) with various stacking sequences of a laminate made of a glass-epoxy composite was considered by Tsai et al. [1] assuming the following geometrical data: R = 12 in, L =5.5 in, β = 0.5, and h = 0.04 in.

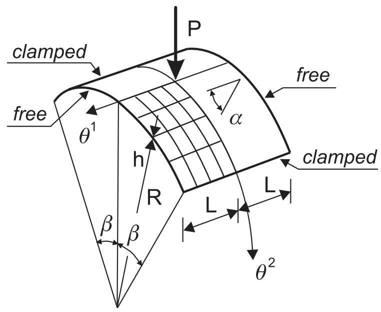

Fig. 1: Clamped cylindrical panel under point load

In the present research a more detailed study on the influence of the degree of orthotropy on the performance of the laminate is presented for selected stacking sequences of a cross-ply laminate (Fig. 2), assuming a variable degree of orthotropy n = 1, 2, 5, 10, 15 and 30. The orthotropic material of a single layer characterized by $E_a = 20.46 \cdot 10^6$ psi, $E_b = E_a / n$, $G_{ab} = G_{ac} = 0.62 \cdot E_b$, $G_{bc} = 0.31 \cdot E_b$, and $\nu_{ab} = 0.313$.

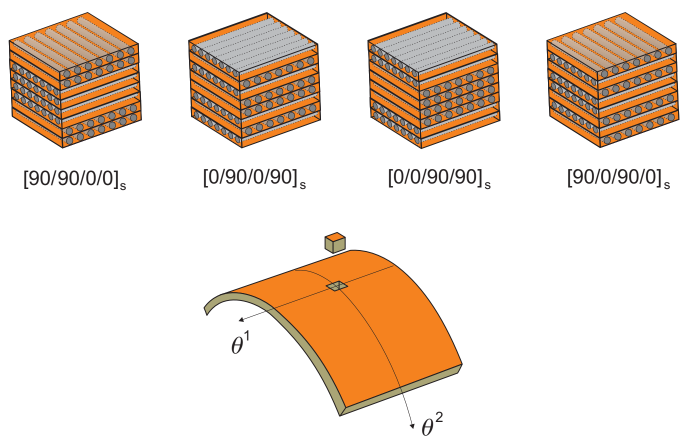

Fig. 2: Various lamination schemes considered for analyzed panel

The geometrically non-linear analysis in the present research is performed with the own FEM code SHL04 [2] based on the large rotation formulation LRT56 [3]. Constitutive relations for composite laminate are constructed assuming the *Equivalent Single Layer* (ESL) model with global constitutive relations established with enhanced *Lamination Theory* adequate for the *First Order Shear Deformation* (FOSD) theory.

2. Results examination

The results of the analysis are presented in Fig. 3 as a graph of the critical snapping load vs. the value of the degree of orthotropy, n, for all four considered cross-ply schemes: $[90/0/90/0]_s$, $[90/90/0/0]_s$, $[0/90/0/90]_s$ and $[0/0/90/90]_s$.

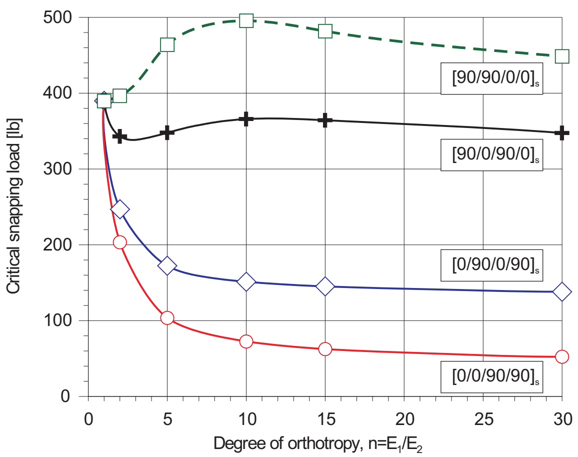

Fig. 3: Interrelation between the degree of orthotropy and the level of critical snapping load

It is quite obvious that a higher bending stiffness could be anticipated for the $[0/90/0/90]_s$ laminate than for the $[0/0/90/90]_s$ one, because in the former case the reinforcement along the θ^2-direction is located closer to the outer surfaces. For the same reason, one can expect to obtain a higher overall bending stiffness by changing the stacking sequence from $[0/90/0/90]_s$ to $[90/0/90/0]_s$ and even a bigger increase of the stiffness can be anticipated for the $[90/90/0/0]_s$ laminate. However, with a little amazement one can observe in Fig. 3 that despite of reduction of the overall panel stiffness accompanying the increase of the degree of orthotropy, the value of the critical snapping load for the $[90/0/90/0]_s$ laminate varies in a very limited range as compared with the previous considered stacking sequences. Even more surprising observation can be made for the $[90/90/0/0]_s$ laminate, where the reduction of the overall stiffness for the increased degree of orthotropy *n* is accompanied quite paradoxically by the increase of the critical snapping load.

3. References

[1] C. T. Tsai, A. N. Palazotto and S. T. Dennis (1991). Large-rotation snap-through buckling in laminated cylindrical panels, *Finite Elements in Analysis and Design* **9**, 65-75.

[2] I. Kreja and R. Schmidt (2006). Large rotations in First Order Shear Deformation FE analysis of laminated shells, *Int. Journal Non-Linear Mechanics* **41**, 101-123.

[3] I. Kreja (2007). *Geometrically non-linear analysis of layered composite plates and shells,* Monographs 83, Gdańsk Universty of Technology, Gdańsk, 1- 173.