STABILITY ANALYSIS OF THE VERY SHALLOW SHELL WITH IMPERFECTION

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1. Introduction

Shells of translation are structural elements very often encountered in the engineering practice. Their middle surface is generated by a vertical curve sliding along another vertical curve. The curves can mostly be circles, ellipses, or parabolas. They occur as parts of aircraft and marine structures in mechanical engineering, create covers of large span structures in civil engineering.

These shells subjected to the external distributed load are liable to the buckling due to dominant compression membrane forces within the shell. It is the reason, why the stability problem has been analysed since the beginning of the twenty century. It was then when the first very slender structures of barrel shells appeared.

Solving stability of the thin shell, it is often insufficient to determine the elastic critical load from eigenvalue buckling analysis, i.e. the load, when perfect shell starts buckling. Nonlinear analysis is necessary, resulting in a full load-displacement response. Basis of this paper is to highlight the difference in the results of these two approaches. It is also necessary to include initial imperfections of real shell into the solution and determine limit load level more accurately. The geometrically nonlinear theory represents a basis for the reliable description of the postbuckling behaviour of the imperfect shell.

Murray and Wilson first presented idea of combining incremental (Euler) and iterative (Newton-Raphson) methods for solving nonlinear problems. Early works involving critical points and snap-through effect were written by Sharifi and Popov, and Sabir and Lock. Using arc-length method to pass limit points on load-displacement paths introduced Riks in [1]. Getting through this problem using displacement control procedure presented Batoz and Dhatt. Detection of critical points using arc-length method was introduced by Wriggers and Simo [2]. Works of Bathe dominate in application of FEM to geometric nonlinear problems, Crisfield [3] incorporated problematic into PC codes.

2. Stability analysis

Illustrative example of steel shallow shell loaded by the external pressure (Fig. 1) is presented. Results of eigenvalue buckling analysis are presented first. They offer an image about location of critical points of nonlinear solution, help with settings in the management of nonlinear calculation process. Results of fully nonlinear analysis follow (ideal shell and structure with initial imperfection).

Presented results were obtained by division on 32x32 elements. Boundary conditions are first considered as simply supported on all edges (UX, UY and UZ applied on all lines), in the latter cases different types of boundary conditions are considered. Element type SHELL181 (4 nodes, 6 DOF at each node) was used. The arc-length method was chosen for analysis, the reference arc-length radius is calculated from the load increment. Only fundamental path of nonlinear solution has been presented.

The difference between the critical load (1st eigenvalue) from eigenvalue buckling analysis and load level in the upper limit point of the load-displacement path of non-linear analysis is significant. Non-conservative results offered from first approach are not applicable to practice.

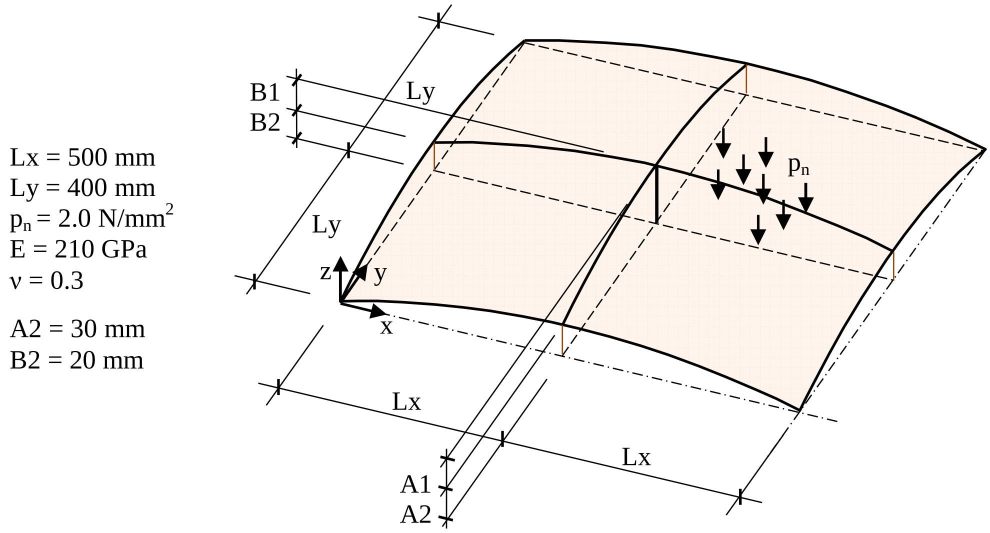

Fig. 1. Shallow shell of translation: notation of the quantities

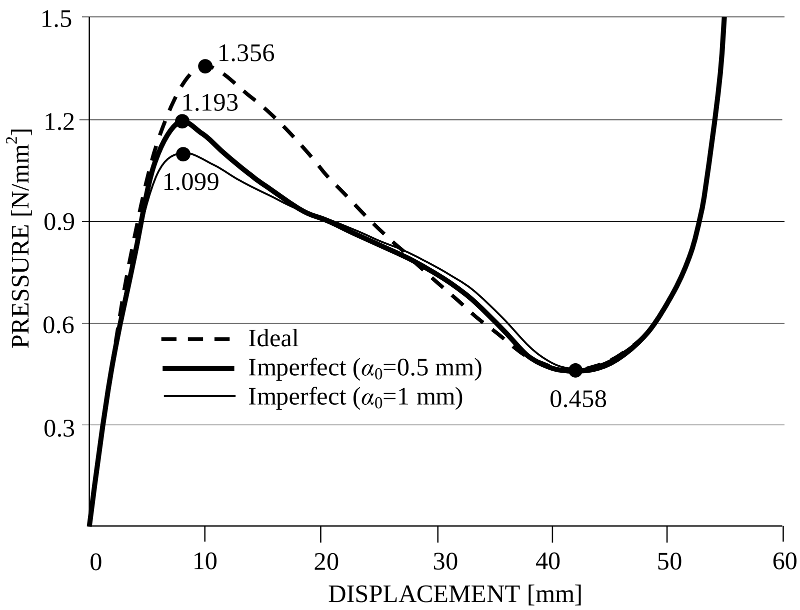

Fig. 2. Fundamental load-displacement path for apex node

Analysis of imperfect shell follows. The shape of initial displacements was created identical to the shape of the 1st eigenmode. Multiplier of the (dimensionless) mode α_0 was assumed 0.5mm and 1mm respectively. Including the effects of imperfections we can see a further decline of load in the upper limit point in comparison with the perfect shell.

References

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