ON DEFORMATIONS OF GEOMETRICALLY NONLINEAR 6-PARAMETER STIFFENED SHELLS

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1. Introduction

Stiffened shells are considered as effective and economical structural configurations, found in many areas of engineering, e.g. civil structures, ship hulls [1]. They could also be found in nature, e.g. in leave's structure.

Due to wide application, there is a need of efficient and accurate numerical models of stiffened shells. Over the years, considerable number of developments have been made in this area. Many results are obtained with Finite Element Method [5][7], but also meshless methods could be incorporated in simulating deformations of shells with ribs [8]. Present research is based on FEM.

2. Theory

In classical beam finite elements, in every node 6 DOFs exists (3 translations and 3 rotations). To achieve consistent kinematics of both shell and beam substructure, it is necessary to provide 6 DOFs also in shell, namely include drilling rotation. In some papers (e.g. [5][7]) simplifications in these field are made – beams kinematics is described only with 3 DOFs (2 translations and 1 rotation), what may lead to oversoft response in nonlinear analysis.

According to best author's knowledge, there is still need of providing patch tests for stiffened plates and shells in large deformation analysis, especially with beams threaten without some simplifications mentioned before.

In present approach, beam elements used to model stiffeners must be placed along shell elements' edges, what limits this approach to basic, orthotropic stiffeners patters. This is not a problem in purely scientific calculations. But in many engineering calculations, independence of shell's and stiffeners' mesh is essential to provide results without numerical problems (e.g. due to mesh distortion) [5][7].

Present formulation is based on well-established nonlinear 6-parameter shell theory [3]. Finite Elements based on this theory provides accurate results in large deformation (large translations and finite rotations) analysis, for elastic shells [4], elastoplastic shells [2] and few other applications. This shell theory incorporate drilling rotation in a natural way. As stiffeners, Cosserat type rods are used. Their theory and FEM basics are described in [6][9]. Both of these theories are based on same root: direct integration of mechanical laws of continuum mechanics.

3. Numerical example

In the numerical example, concentrically stiffened quarter-ring cantilever is considered. Geometry, material and load data is presented in Fig. 1a). Load-deflection curves are obtained with authors numerical code and commercial Abaqus code. In present calculation, 4x20 CAM 16-noded fully integrated elements in shell and 20 B6 4-noded beam elements in each rib are used. Results of the analysis (Fig. 1b) show excellent convergence between authors and commercial code, what proves reliability of authors code.

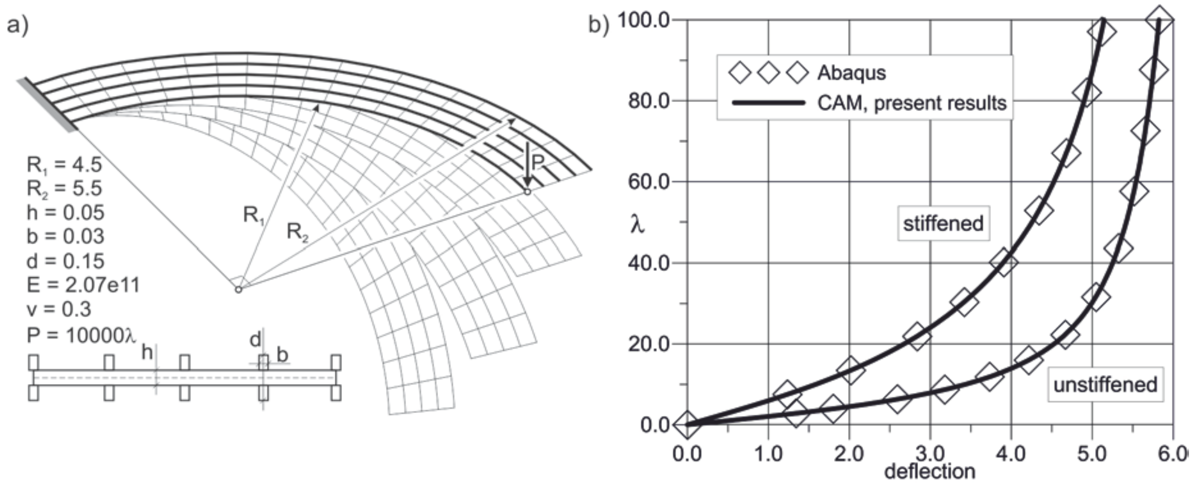

Figure 1. Stiffened quarter-ring cantilever a) geometry, material and load parameters, deformation b) load factor-deflection curves.

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5. References

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