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AN ISOGEOMETRIC LOCKING-FREE NURBS-BASED SOLID-SHELL ELEMENT FOR GEOMETRIC NONLINEAR ANALYSIS

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With the introduction of IsoGeometric Analysis (IGA) [1], the calculation of shell-type structures has become possible using the exact geometry of the structure regardless of the mesh density. For that, Lagrange polynomials are replaced by NURBS functions, the most commonly used technology in Computer-Aided Design, to perform the analysis. In addition, NURBS functions have a higher order of continuity at knots, which leads to higher per-degree-of-freedom accuracy of the shell solution than with classical Finite Elements Analysis (FEA). However, NURBS elements are likely to suffer from the same locking problems as classical elements. Then, to really benefit from NURBS, some strategies need to be implemented to answer the locking issue.

Besides the initial idea of increasing the order of approximation [1, 2], it has been seen for the particular case of solid-shell elements that implementing a mixed method or making use of a Bbar projection could greatly improve the accuracy of the solution [3]. Until now, these locking-free solid-shell elements only work in small strain linear elasticity. As it is known in classical FEA that the solid-shell elements are well suitable for large deformations (easy treatment of large rotations and straightforward procedure of updating configurations, with no rotational degrees of freedom involved) [4], it appears worthwhile to extend the method in IGA to non-linear analysis. Moreover, regarding now the more global field of NURBS shell, some other locking-free elements have been proposed for small displacements and rotations (see, e.g., [5]), but very few of them have been extended to large deformations.

In this context, we develop here a solid-shell NURBS element for geometric nonlinear applications. A single layer of elements is considered through the thickness of the shell. The shell is elastic but is subjected to large deformations. An extension of the mixed method presented in [3] is proposed to handle large deformations and large rotations.

The mixed tangent matrix is derived and a hourglass control is implemented to overcome the appearance of spurious modes.

To begin with, some linear buckling analysis are performed and show the ability of the elements to quickly approach the buckling load and mode. Then, usual test cases involving geometric nonlinear computations are carried out. They reveal the superiority of the proposed method, in terms of coarse mesh accuracy, over the standard higher-order NURBS solid-shell one and, over other NURBS shell published techniques. For example, the pinched hemispherical shell has been computed (see figure 1). It can be observed that, for a mesh composed of eight elements by side, only the solution of the proposed 2^{nd} order mixed solid-shell element (black curve) seems to fit the reference (circles). For the basic NURBS elements (i.e. based on a standard displacement formulation), even a polynomial order of four lengthwise (red dotted line) is not sufficient to obtain the good solution at the end of the simulation.

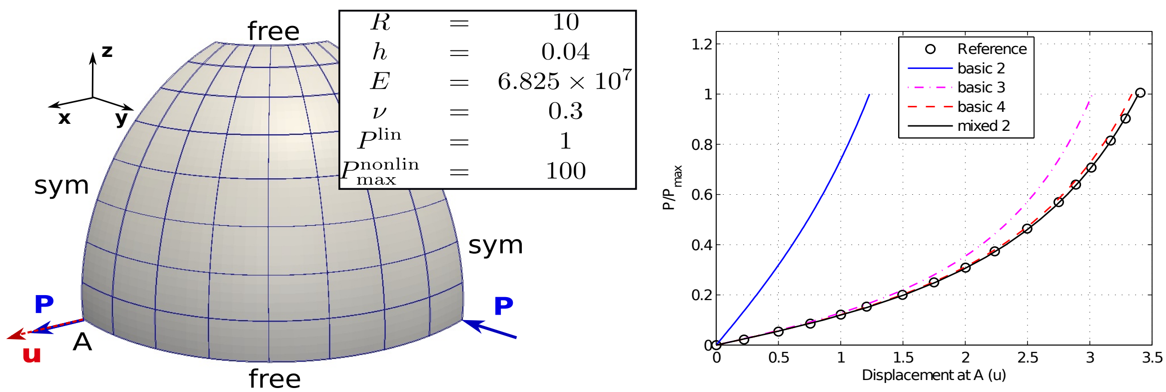

Figure 1: Pinched hemispherical shell with hole: load-displacement curves with 8×8 solid-shell basic 2^{nd} order, 3^{rd} order, 4^{th} order, and mixed 2^{nd} order elements .

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