Modeling of Gridshell Structures using Isogeometric Approach

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ABSTRACT

Exact geometry representation in Isogeometric analysis can significantly enhance the analysis of arbitrarily curved beams. Isogeometric formulation of the three-dimensional curved beam element based on Timoshenko theory has been already introduced [3]. The biggest drawback of the formulation is that the element suffers from numerical locking, which can enormously deteriorate the overall computational performance.

To overcome numerical locking the analogous techniques to standard FEM locking treatment have been studied [1, 2]. While in the standard finite elements the reduced integration is widely used for its computational performance, in case of Isogeometric analysis this approach deals with complicated determination of optimal reduced integration rules, which vary according to the particular degree and inter-element continuity. Another proposed methods, $\bar{B}$-method and DSG method, can be generally used for any combination of degree and continuity, nevertheless both methods lead to the higher computational cost.

The goal of the contribution is to present the application of the isogeometric beam elements to the analysis of gridshell structures. These structures are formed from initially straight grid of pointwise connected beams (usually wooden) which is subsequently deformed into the desired shape. To model such a structure, the formulation of the element has to be extended to the geometrically nonlinear analysis and the possibility to model joints has to be introduced.

The element with locking treatment ($\bar{B}$ / DSG) has been implemented into OOFEM finite element code [4]. One of the modeling possibilities of gridshell joints is to enforce the compatibility using Lagrange multipliers. However, this approach leads to the concentrated force and moment loadings which in combination with the higher continuity of B-spline basis functions lead to the oscillations in numerical solution. To overcome the problem the continuity can be reduced by inserting the knots into the joints and increasing the knot multiplicity. This approach basically splits the beams into individual grid segments modeled by separate elements. In the contribution the comparison of the above mentioned approaches will be presented.

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REFERENCES

[1] R. Bouclier, and T. Elguedj, Locking free isogeometric formulations of curved thick beams, *Comput. Methods Appl. Mech. Engrg.*, Vol. **245-246**, pp. 144-162 (2012).

[2] R. Echter, and M. Bischoff, Numerical efficiency, locking and unlocking of NURBS finite elements, *Comput. Methods Appl. Mech. Engrg.* Vol. **199**, pp. 374-382 (2010).

[3] G. Zhang, R. Alberdi, and K. Khandelwal, Analysis of three-dimensional curved beams using isogeometric approach, *Engineering Structures*, Vol. textbf117 pp. 560-574 (2016).

[4] B. Patzák, OOFEM project home page. http://www.oofem.org, 2018.