Three-Dimensional Isogeometric Curved Beam Element with Locking Treatment and Its Computational Performance

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ABSTRACT

Isogeometric approach has indisputable benefits for the analysis of curved beams of arbitrary geometries. The exact geometry representation can enormously enhance the accuracy and time efficiency of the analysis. As well as the standard finite elements, the IGA-based Timoshenko elements suffer from the numerical locking. This is probably the biggest drawback of existing element formulations as it can rapidly deteriorate overall computational performance.

To overcome locking phenomena, several locking removing techniques have been proposed [1, 2]. These techniques are analogous to locking treatments originally developed for standard finite elements. The most promising ones seems to be selective reduced integration, $\bar{B}$-method, and Discrete Shear Gap (DSG) method.

The reduced integration is widely used in classical finite elements for its good performance and computational efficiency. In case of isogeometric analysis the higher inter-element continuity makes it difficult to find general rule which would determine the appropriate integration schemes for arbitrary degree and continuity. On the contrary, $\bar{B}$-method and DSG method can be generally used for any combination of degree and continuity, but these methods lead to the full stiffness matrix at patch level and thus can significantly increase the computational cost.

The presented study aims to compare isogeometric formulations with different locking treatment with standard straight Timoshenko beam element with cubic approximation which is naturally locking-free. The three-dimensional isogeometric curved beam element [3] has been implemented into the existing finite element code. Several benchmarks have been run and the solution time needed to achieve given levels of accuracy have been analysed. Obtained data enables the comparison of the computational efficiency of isogeometric approach with different locking removal techniques and standard finite elements.

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