Locking-free isogeometric collocation formulation for geometrically exact curved Timoshenko beams

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ABSTRACT

Isogeometric collocation (IGA-C) is a new computational method recently proposed in [1] based on the discretization of the strong form of the governing equations. The method exploits geometric flexibility and higher accuracy of isogeometric analysis (IGA) [2] and, at the same time, takes advantages of the complete elimination of numerical quadrature. Since IGA-C requires only one point evaluation per degree of freedom, it results much faster than standard Galerkin-based IGA and Galerkin-based finite element analysis [3]. IGA-C has already been successfully applied to several geometrically linear problems both in one and two dimensions. Very recently the method has been extended to geometrically exact shear-deformable beams [4, 5]. Continuing along the path opened in [4], where a displacement-based formulation for initially straight beams was proposed for the first time, this contribution presents a displacement-based and a mixed isogeometric collocation formulations for three-dimensional geometrically exact shear-deformable beams with arbitrarily curved initial geometry. Strong forms of both formulations are consistently linearized with respect to the underlying configuration manifold. High efficiency is achieved by using a geometrically consistent kinematic model in which incremental rotations are parametrized through the spatial rotation vector. Several numerical tests demonstrate that the proposed mixed formulation is totally locking-free for any choice of approximation degree. Mixed formulation also exhibits higher robustness in the incremental-iterative algorithm. Elimination of shear locking and low computational cost assured by the combination of isogeometric collocation and the chosen consistent kinematic model result in an efficient, accurate and geometrically powerful method able to handle geometrically complex beam problems.

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