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Chebyshev Collocation Method for the Free Vibration Analysis of Geometrically Exact Beams with Fully Intrinsic Formulation

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Abstract

A Chebyshev collocation method is presented for the free vibration analysis of geometrically exact nonlinear beams with fully intrinsic formulation. The intrinsic formulation of the governing equations of the beam contains neither displacement nor rotation variables. The proposed collocation discretization technique is based on the Chebyshev points as the collocation points and the orthogonal Chebyshev polynomials as the trial functions. This method is successfully applied to the eigenvalue analysis of the linearized intrinsic governing equations of a nonlinear beam. A number of test cases have been considered for either straight or pretwisted beams and the obtained results are compared to the analytical, numerical as well as experimental results. In order to show the applicability of current approach for real-life engineering problems, a composite wind turbine rotor blade with non-uniform distribution of properties is also considered. In all test cases a very good concordance has been observed. The proposed method bypasses the integrations common in finite element based methods and difficulties associated with finite rotations interpolation and while exhibiting a very good accuracy compared to the finite element results, it is computationally more efficient and simpler to implement in a computer programming code.

Keywords: Chebyshev Collocation Method, Geometrically Exact Beam, Intrinsic Formulation, Free Vibration, Pretwisted Beam, Composite Rotor Blade, Composite Beam

1. Introduction

In the context of the mathematical modeling of geometrically nonlinear beams the so called geometrically exact theories have attracted a great deal of attentions so far. In the geometrically exact beam theories no specific assumptions are made with regards to the displacement field of the beam and the finite rotations are utilized for the kinematical description of the beam deformations which make these kinds of beam theories, among other theories, the most versatile and the most loyal to the true nature of the beam problem. The pioneering work of Reissner (1973) on the statics of geometrically exact beams has been the source of

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