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A TRULY LARGE STRAIN ROD MODEL THAT INCORPORATES GENERAL CROSS-SECTIONAL IN-PLANE CHANGES AND OUT-OF-PLANE WARPING

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ABSTRACT

The main purpose of this work is to present a fully nonlinear geometrically-exact multi-parameter rod model that incorporates general in-plane cross-sectional changes as well as general out-of-plane cross-sectional warping. The formulation constitutes an extension of the earlier works presented earlier, in the sense that the restrictions to a rigid cross-section and to a Saint-Venant-like elastic warping are now removed from the theory.

Our approach defines energetically conjugated cross-sectional resultants in terms of generalized stresses and strains, based on the concept of a cross-section director. Besides their practical importance, the use of cross-sectional resultants simplifies the derivation of equilibrium equations and the enforcement of boundary conditions, in either weak or strong senses. In addition, the corresponding tangent bilinear weak form is obtained in a more expedient way, rendering always symmetric for hyper-elastic materials and conservative loadings (even far from equilibrium states).

With the developed model, fully three-dimensional finite strain constitutive equations can be employed with no spurious stiffening. The ideas are general and extension to inelastic rods, in particular to those of elastoplastic materials, is straightforward once a stress integration scheme within a time step is at hand. Several numerical examples with the aid of the Finite Element Method are shown, in order to illustrate the power and robustness of the formulation. Special attention is given to the issue of locking due to incompressible materials.

Furthermore, the present assumptions allow a consistent basis for the proper representation of profile (distortional) deformations, which are typical of cold-formed thin-walled rod structures. We believe this is one of the main features of our formulation, as the use of more complex shell models in order to capture such phenomena becomes unnecessary.

REFERENCES

[1] J.C. Simo, “A finite strain beam formulation”. The three-dimensional dynamic problem. Part I. *Computer Methods in Applied Mechanics and Engineering*; 49, 55-70, 1985.

[2] A. Cardona and M. Gerardin, “A beam finite element non-linear theory with finite rotations”, *Int. J. Numer. Meths. Engrg*.; 26, 2403-38, 1988.

[3] P. M. Pimenta, T. Yojo, “Geometrically-exact analysis of spatial frames”, Applied Mechanics Reviews, ASME, New York, v.46, 11, 118-128, 1993.

[4] P. M. Pimenta, E.M.B. Campello, “A fully nonlinear multi-parameter rod model incorporating general cross-section in-plane changes and ou-of-plane warping”, Latinamerican Journal of Solids and Structures, 1 (1), 119-140, 2003.