Large-displacement analysis of composite laminated beams through a position-based finite element formulation

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Abstract

This study presents a positional finite element approach for the nonlinear static analysis of composite laminated beams. The proposed model takes inspiration from the formulation developed by Valvo [1], by adding rotational degrees of freedom into the unknown vector. Specifically, a two-node curved laminated beam finite element is formulated adopting an interpolation scheme based on Hermite polynomials, as first proposed by Armero [2]. Therefore, our positional model exhibits the same advantages of the latter in terms of accuracy and frame invariance, also avoiding the problem of membrane locking. Geometrical nonlinearities are considered by using the Green-Lagrange measure of axial strain and the change in geometric curvature between the reference and current configurations. Furthermore, any hyper-elastic constitutive law can be easily implemented, including elastic couplings if present. The governing nonlinear equilibrium equations are obtained through the principle of stationary total potential energy and numerically solved via a suitable arc-length method. Several examples are presented to illustrate the effectiveness of the proposed approach.

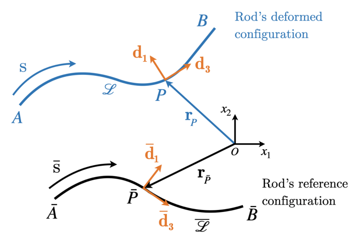

Figure 1: Reference and deformed configurations of a curved beam.

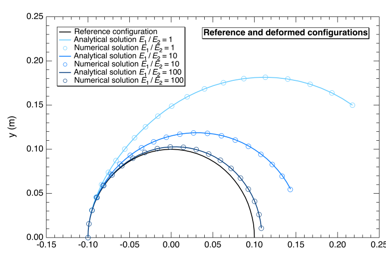

Figure 2: Semicircular bimaterial cantilever beam with a horizontal force at the free end.

References

[1] Valvo PS, "Symmetric stiffness matrices for isoparametric finite elements in nonlinear elasticity", *Comput Mech* (2025) 75: 919-943.

[2] Armero F, "A new Hermite finite element for nonlinear Kirchhoff rods: The plane case", *Int J Numer Methods Eng* (2024) 125: e7448.