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BENDING DIRECTION REVERSAL IN PRESSURIZED SLENDER HYPERELASTIC ECCENTRIC TUBE: A REGIME MAP OF THE MOONEY–RIVLIN PARAMETER SPACE

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ABSTRACT

This study reports a marked influence of Mooney Rivlin material parameter space on computational mechanics of slender tubes with an eccentric hole, with fixed free end boundary conditions and closed ends. Using the strain energy function

$$W = C_{10}(I_1 - 3) + C_{01}(I_2 - 3),$$

a systematic investigation of the (C_{10}, C_{01}) space combines structured grid sampling with targeted random sampling near regime transitions to assess how constitutive sensitivity to strain invariants governs bending behavior. Finite element simulations reveal three distinct deformation regimes: left bending (thicker side), right bending (thinner side), and a neutral regime characterized by negligible curvature. Bending direction is classified by the sign of the tip displacement U_x, with cases satisfying $|U_x| < 0.0015$ units where deflection is normalized with axial tube length as the predesignated boundary for classification.

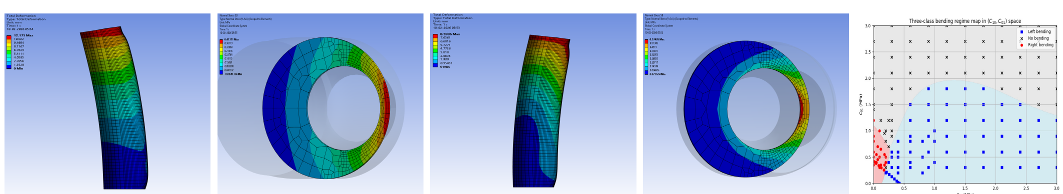

Figure 1: (a) Left-bending. (b) Axial Stress (L). (c) Right-bending. (d) Axial Stress (R). (e) Bending regime map.

The resulting regime map exhibits a well-defined, nonlinear transition boundary. C_{10}-dominated region favour left bending with tensile axial strain in the thinner wall, whereas C_{01}-dominated region promote right bending with compressive axial strain, representing a complete deformation mode reversal. At elevated C_{01} values, bending is progressively suppressed, as we observe more or less uniform distribution of axial stress and stretch across the cross-section. The C_{01} regime consistently exhibits higher peak axial stress, radial stress sign reversal, and pronounced cross-sectional ovalization.

Analysis indicates that bending reversal arises from constitutive–geometric coupling that redistributes axial stretch under near-incompressibility constraints, rather than from differences in overall material stiffness. Support vector machine classification is employed to delineate regime boundaries, providing quantitative design guidance. These findings underscore the importance of material parameter selection using computational mechanics for predicting deformation mechanisms.

REFERENCES

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