Material and Prestrain Identification of Spatially Heterogeneous Isogeometric Thin Shells

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Characterizing the prestrain of biological shells and their material properties is crucial for accurate numerical modeling. Prestrain identification belongs to the class of problems involving the recovery of stress-free configuration. In many cases, the external loads acting on a body are known, whereas only the deformed, non-stress-free geometry can be observed. In this study, the previously developed Finite Element Model Updating inverse framework [1, 2, 3] is extended to identify simultaneously prestrain and spatially varying material properties. The thin shells are directly formulated on the mid-surface and adopt Kirchhoff–Love kinematics with large deformations. Three surface configurations are introduced: the reference (unstrained and stress-free), intermediate (prestrained), and current (prestrained and under external loads). This leads to a multiplicative split of the surface deformation gradient into prestrain and load-strained parts [4]. The forward problem is solved numerically with rotation-free isogeometric analysis [5]. The inverse problem assumes that the intermediate and current surface configurations are known, whereas the reference one remains unspecified. The prestrain and material properties fields are described using low-order Lagrange elements, known as the material mesh [1], whose nodal values become the unknowns to be identified. The identification is carried out through PDE-constrained optimization, where the minimized objective function consists of the least square error between experimental full-field displacements and their numerical counterparts. To solve this task, the Trust-Region Interior Reflective approach, supplied by the analytical derivatives of the objective function, is employed. Verification of the proposed inverse approach is performed with numerical examples based on synthetic data corrupted by noise. The results indicate that the presented framework can reconstruct the prestrain and spatially varying material properties provided that certain assumptions are met, such as an appropriate material mesh and full-field data with high information content. The scope of examined constitutive relations includes isotropic ones, in particular Koiter, Neo-Hooke, and Canham models.

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