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Spherical indentation method for determining the constitutive parameters of hyperelastic soft materials

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A comprehensive study on the spherical indentation of hyperelastic soft materials is carried out through combined theoretical, computational and experimental efforts. Four widely used hyperelastic constititutive models are studied, including neo-Hookean, Mooney-Rivlin, Fung, and Arruda-Boyce models. Through dimensional analysis and finite element simulations, we establish the explicit relations between the indentation loads at given indentation depths and the constitutive parameters of materials. Based on the obtained results, the applicability of Hertzian solution to the measurement of the initial shear modulus of hyperelastic materials is examined. Furthermore, from the viewpoint of inverse problems, the possibility to measure some other properties of a hyperelastic material using spherical indentation tests, e.g. locking stretch, is addressed by considering the existence, uniqueness and stability of the solution. Experiments have been performed on PDMS to validate the conclusions drawn from our theoretical analysis. The results reported in this study should help identify the extent to which the mechanical properties of hyperelastic materials could be measured from spherical indentation tests.

Keywords: Spherical indentation; hyperelastic soft materials; Dimensional analysis; Finite element method; Inverse problem