Elastostatic fields near the crack front in an initially stressed hyperelastic solid : mechanical and numerical analysis

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with
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The presence of initial stress in natural and manufactured materials and structures has been known for a long term and it is experimentally well attested in diverse scopes from biomechanics, geophysics, to welded structures and manufacturing. From a physical viewpoint, the initial stress can be a result of incompatible growth and/or plasticity deformation processes and then alters the mechanical properties and the stress distribution. This deformation incompatibility generates singularity due to stress concentration at the micro, meso and macro-scale. Other types of singularities are also present in structures like cracks, corners, voids, inclusions, and other material or geometrical imperfections.

The objective of this work is the analysis of the initial stress influence on the mechanical fields near a crack front in a particular incompressible hyperelastic solid.

The considered threedimensional transformation here is an in-plane deformation superposed to an antiplane one towards a particular generalization of the three-dimensional Linear Elastic Fracture Mechanics (LEFM). The resulted different mechanical fields are functions of the eigenvectors orientation relative to the crack plane and also a weighting parameter relating the shear modulus and the eigenvalues of the initial stress field. Using a set of mathematical transformations, an analogy can be illustrated between the boundary value problem equations for both initially stressed NeoHookean and the unstressed one. Hence, a comparison between the initially-stressed and the unstressed materials has been done through the different asymptotic expansions for multiple mechanical fields. In addition, it is shown that the initial stress field can contribute to the rotation of the crack front and it has an influence on the crack opening shape. Additionally, the initial stress creates a sort of perturbation (oscillations) of the asymptotic solution for the different mechanical fields compared to the unstressed case. Then, the extremums of the different mechanical fields from the displacement and the Cauchy stress components to the strain energy depend on the spectral parameters of the initial stress.

The results obtained in the present work are used for numerical purposes. In fact, the displacement and the pressure asymptotic fields are exploited to enrich the FEM basis leading to a new variant of the XFEM method. A convergence-stability study is then achieved.

References

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