Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Growth and instability of soft tissue in confined environment

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ABSTRACT

Soft tissues are complex materials with typical nonlinear, anisotropic, inhomogeneous behaviors subjected to large strains and stresses. Growth or atrophy of soft materials (refer both of them as growth in the next) in media may lead to instability and formation of surface wrinkling, folding or creasing which depends on a variety of factors, such as geometry and material properties. Instabilities in the soft materials to adjust the shape configuration and dictate morphological evolution is playing a crucial role in the healthy behavior of soft biological tissues like artery, heart, brain, and airway. Inappropriate growth process may cause physiological and pathological disorders in organs such as asthma, mucosal inflammation, gastroenteritis, chronic bronchitis, and tumor invasion. Growth of soft biological materials without confined boundary condition has been studied analytically and numerically in several recent articles [1]. The results show that growth induces residual stresses in the material that often cause large enough compressive stress to initiate instability in the structures [2]. However, constrained or anisotropic growth in the soft materials remains to be further explored. This article presents an isotropic growth of a tube with Neo-Hookean hyperelastic material in the confined boundary. To produce the deformation field and stress distributions, multiplicative decomposition of deformation gradient theory has been adapted and critical growth factors for trigger of creases or detaching have been calculated analytically and numerically. Free energy content of creased structure can be calculated and compared with energy content of deformed but without creases status. Result shows creased or detached tubes have lower energy content and releasing of energy by creasing causes system to be more stabilized. These primary results may provide some fundamental understandings to growth modeling of complicated phenomenon like cortical folding of brain.