Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Computational modeling of biomechanics: biological growth and morphogenesis

Li, Jiaoyan; Zhang, Lijie; Lee, James, The George Washington University, United States

ABSTRACT

Unlike common engineering materials, living matter can autonomously respond to environmental changes to become stronger, weaker, larger, or smaller within months, weeks, days, or even seconds as a result of a continuous microstructural renewal and adaption. The importance of mechanics in developmental biology is well established, where biomechanical forces and constraints are the bridge that connects genetic and molecular-level events to tissue-level deformations that shape the developing embryo. Moreover, feedback from the mechanical environment affects gene expression and differentiation. Therefore, mechanical forces and constraints are not only a proximal cause of biological growth and morphogenesis, but also play a regulatory role. Regarding the simulation of these processes, however, it is important to recognize that mathematical models can never include all of the complexities inherent in biological systems. Rather, they are ad hoc constructions designed to help understand some aspect of the system. In this sense, continuum mechanics, accompanied by growth theories, provide the theoretical framework for the computational modeling of biological growth and morphogenesis. In this article, we proposed an advanced continuum theory by integrating with the growth theory, proposed by Rodriguez et al. [1]. The shape change of a load-free tissue during growth is described by a mapping analogous to the deformation gradient tensor. This mapping is decomposed into a transformation to a local zero-stress grown state and an accompanying deformation that ensures the compatibility of the total growth deformation. Beyond autonomous growth, the geometric constraints confine the tissue developments, which are usually irreversible processes. Here, we propose to introduce plastic deformation to simulate the irreversible development and adopt return mapping algorithm for the numerical simulation. It is noticed that most biological growth and morphogenesis behaviors involve large deformation. Hence, we constructed a large strain theory of plasticity which is based on the Lagrangian description of balance laws and constitutive relations and incorporates the fundamental features of the aforementioned growth theory. To verify our theory and the corresponding code, several sample problems will be shown and discussed.

REFERENCE

[1] Rodriguez, E.K., Hoger, A., McCulloch, A.D., 1994. Stress-dependent finite growth in soft elastic tissue. *J Biomechanics.* 27, 455–567.