A Multiphysics Computational Modeling of Smart Magnetic-Sensitive Soft Matters

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Abstract

A multiphysics model is presented for simulation of the responsive behavior of the magnetic-sensitive hydrogel, with the effects of magneto-chemo-mechanical coupled fields, which is termed the multieffect-coupling magnetic-stimulus (MECm) model. In this work, the magnetic susceptibility for magnetization of the general magnetic hydrogel is defined as a function of finite deformation, instead of a constant for an ideal magnetic hydrogel. The present constitutive equations, formulated by the second law of thermodynamics, account for the effects of the chemical potential, the externally applied magnetic field, and the finite deformation. In particular, a novel free energy density is proposed with consideration of the magnetic effect associated with finite deformation, instead of volume fraction. After examination with published experimental data, it is confirmed that the MECm model can well capture the responsive behavior of the magnetic hydrogel, including the deformation and its instability and hysteresis under a uniform or nonuniform magnetic field. The parameter studies are then presented for influences of the magnetic and geometric properties, including the magnetic intensity, shear modulus, and volume fraction of the magnetic particles, on the behavior of the magnetic hydrogel, for a deeper insight into the fundamental mechanism of the magnetic hydrogels.

A short Biography

Dr. Hua Li received his B.Sc and M.Eng degrees in Engineering Mechanics from Wuhan University of Technology, P.R.C., in 1982 and 1987, respectively. He obtained his Ph.D degree in Mechanical Engineering from the National University of Singapore in 1999. From 2000 to 2001, Dr. Li was a Postdoctoral Associate at the Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign. At the end of 2005, he was a Visiting Scientist on invitation at the Department of Chemical and Biomolecular Engineering in Johns Hopkins University. From 2001 to 2006, he was a Research Scientist in the A*STAR Institute of High Performance Computing. Dr Li joined NTU as an Assistant Professor in June 2006 and he was promoted to Associate Professor in March 2013. He is currently in the School of Mechanical & Aerospace Engineering at NTU. His research interests include the multiphysics modelling of soft matters (smart hydrogel in BioMEMS and biological cell in microscale fields); development of highly efficient numerical computational methodology (meshless & multiscale algorithms); simulation of sustainable energy (building energy efficiency and fuel cell system); and structural dynamics (high-speed rotating shell and composite materials structure). He has sole-authored a monograph book entitled “Smart Hydrogel Modelling” published by Springer, co-authored three monograph

books entitled "Reduced Modelling of Planar Fuel Cells – Spatial Smoothing and Asymptotic Reduction" by Springer, "Meshless Methods and Their Numerical Properties" by CRC Press and "Rotating Shell Dynamics" by Elsevier, and 2 book chapters, one on MEMS simulation and the other on hydrogel drug delivery system modelling, and authored/co-authored over 150 articles published in peer-reviewed international journals. He received the Silver Award in HPC Quest 2003 - The Blue Challenge presented by IBM & IHPC in 2003, and Winner of Top Project of the Singapore Maritime Institute Forum – Research Showcase 2015. He is also extensively funded by agencies, such as NRF, EDB and SMI, including the principal investigator of a computational BioMEMS project awarded under A*STAR's strategic research programme in MEMS, and by industries, including SUN Microsystems (Oracle), Sony, Philips, Lloyd's Register, Emerson, ABB, DSO and JTC.