The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Immersed Boundary Analysis of Models with Internal State Variables: Applications to Hydrogels

Jorge L. Barrera[1] and Kurt K. Maute[2]

[1] Computational Engineering Division, Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, California 94550, United States of America

[2] Department of Aerospace Engineering Sciences, University of Colorado at Boulder, 3775 Discovery Driver, Boulder, Colorado 80303, United States of America

Keywords: *Immersed boundary analysis, XFEM, Internal state variable, Hydrogels*

Research on soft active materials has flourished in recent years driven mainly by potential applications to actuation systems, tissue engineering, and soft robotics. These applications benefit from the unique properties of soft active such as large deformations, a wide range of stimulants, and high motion complexities. Hydrogels are among the dominant members of this group of materials. The highly nonlinear chemo-mechanical transient behavior of these is described by partial differential equations that advance in time through internal state variables representing the swelling state of the gel. Hence, the analysis of components/devices using these materials require intricate mathematical models that accurately predict their response and stabilization schemes capable of handling the mentioned model intricacies. This presentation will introduce an immersed boundary analysis technique suitable to simulate models with internal state variables for accurate and stable computation of gradients of the materials response. The proposed analysis framework uses level sets for describing the material layout in a background fixed mesh and a generalized version of the extended finite element method ([1]) for predicting the response. Computational aspects of the implementation of this approach for a highly nonlinear, transient, couple-physics hydrogel model ([2]) are discussed. The effect of the internal state variable on the stability of physical analysis is examined with numerical examples in 2D and 3D. Despite focusing on hydrogels, the presented theory can be extrapolated to similar applications using models with internal state variables (e.g., shape memory polymers) and immersed boundary analysis technique (e.g., CutFEM).

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, IM Review Number: LLNL-ABS-829968.

REFERENCES

[1] Villanueva, Carlos H., and Kurt Maute. Density and level set-XFEM schemes for topology optimization of 3-D structures. *Computational Mechanics* 54.1 (2014): 133-150.

[2] S. A. Chester, C. V. Di Leo, L. Anand, A finite element implementation of a coupled diffusion-deformation theory for elastomeric gels, *International Journal of Solids and Structures* 52 (2015) 1–18.