Isogeometric Finite Element Modeling of Phase Fields on Deforming Surfaces

Roger A. Sauer*[1], Christopher Zimmermann[1], Kranthi K. Mandadapu[2] and Thomas J.R. Hughes[3]

[1] Aachen Institute for Advanced Study in Computational Engineering Science (AICES)
RWTH Aachen University
Templergraben 55, 52062 Aachen, Germany
e-mail: sauer@aices.rwth-aachen.de, zimmermann@aices.rwth-aachen.de
web page: www.aices.rwth-aachen.de

[2] Department of Chemical and Biomolecular Engineering
University of California, Berkeley
201 Gilman Hall, Berkeley, CA, USA
e-mail: kranthi@berkeley.edu - web page: http://www.chemistry.berkeley.edu/cbe

[3] Institute for Computational Engineering and Sciences (ICES)
The University of Texas at Austin
201 East 24th St, Austin, Texas, USA
e-mail: hughes@ices.utexas.edu - web page: https://www.ices.utexas.edu

ABSTRACT

A phase field model on deforming surface structures is presented. The surface is modeled as a thin (Kirchhoff-Love) shell, based on the rotation-free finite element formulation of [1]. Rotation-free shell formulations and high-order phase field models necessitate an at least C^1-continuous spatial discretization across element boundaries. To achieve this, NURBS-based isogeometric finite elements are used. A standard NURBS-based representation of complex geometries requires several NURBS patches. Since the C^1-continuity is lost at patch interfaces, a continuity constraint is presented to enforce the C^1-continuity across patch interfaces. Another approach for modeling complex geometries is by using unstructured meshes based on T-splines.

The phase separation of a binary mixture that is governed by the Cahn-Hilliard equation is studied on deforming shells. A monolithic coupling formulation of the phase field and the mechanical field is proposed. The material behavior of the shell is considered to depend on the local phase state. The phase separation process therefore directly affects the mechanical behavior. An adaptive time-stepping algorithm for the coupled formulation is proposed. The algorithm incorporates both, the error of the phase field and the mechanical field. Numerical examples are presented for a torus with a structured mesh and a double torus (genus-two surface) with an unstructured mesh.

REFERENCES

[1] Duong, T.X., Roohbakhshan F. and Sauer R.A., "A new rotation-free isogeometric thin shell formulation and a corresponding C^1-constraint for patch boundaries". *Comp. Meth. Appl. Mech. Engrg.* Vol. **316**, pp. 43–83, (2017).