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

An arbitrary Lagrangian-Eulerian formulation for Navier-Stokes flow on deforming surfaces

Roger A. Sauer[1,2,3]

[1] Faculty of Civil and Environmental Engineering, Gdańsk University of Technology, ul. Gabriela Narutowicza 11/12, 80-233 Gdańsk, Poland, roger.sauer@pg.edu.pl
[2] Aachen Institute for Advanced Study in Computational Engineering Science (AICES), RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany
[3] Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Assam 781039, India

Keywords: *Fluidic membranes, fluid-structure interaction, nonlinear finite element methods, lipid bilayers*

A new arbitrary Lagrangian-Eulerian (ALE) formulation for incompressible Navier-Stokes flow on deforming surfaces is presented. The new formulation extends the surface ALE formulation of [1] to more general surface motions. It is based on a new curvilinear surface parameterization that describes the motion of the ALE frame. Its in-plane part becomes fully arbitrary, while its out-of-plane part follows the material motion of the surface. This allows for the description of flows on deforming surfaces using only surface meshes. The unknown fields are the fluid pressure, fluid velocity and surface motion, where the latter two share the same normal velocity. The new theory is implemented in the nonlinear finite element framework of [2] using the stabilization scheme of [3] for the incompressibility constraint. The implementation is verified through several manufactured steady and transient solutions, obtaining near optimal convergence rates in all cases. The new formulation allows for a detailed study of fluidic membranes such as soap films, bubbles and lipid bilayers.

REFERENCES

[1] A. Sahu, Y.A.D. Omar, R.A. Sauer and K.K. Mandadapu, Arbitrary Lagrangian-Eulerian finite element method for curved and deforming surfaces: I. General theory and application to fluid interfaces, *J. Comput. Phys.*, **407**:109253, 2020

[2] R.A. Sauer, Stabilized finite element formulations for liquid membranes and their application to droplet contact", *Int. J. Numer. Meth. Fluids*, **75**(7):519-545, 2014

[3] C. R. Dohrmann and P. B. Bochev, A stabilized finite element method for the Stokes problem based on polynomial pressure projections. *Int. J. Numer. Methods Fluids*, **46**:183-201, 2004