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AN IMMERSED SMOOTHED FINITE ELEMENT METHOD FOR ANALYZING FLUID-STRUCTURE INTERACTION SYSTEMS CONSISTING OF DIELECTRIC ELASTOMERS

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As a class of light weight, low cost, and soft active materials, dielectric elastomers (DEs) have attracted increasing attentions due to their ability to undergo large strains in response to an imposed electric field. When a thin dielectric elastomer membrane sandwiched between two compliant electrodes is subject to a voltage potential, the membrane reduces its thickness and expands its area significantly. This electromechanical behavior has led to intense efforts to develop highly deformable and flexible actuators for a wide range of applications, such as modern soft robots, artificial muscles and so on. Besides actuators, dielectric elastomers also show in recent studies a great potential in harvesting energy from ocean waves [1].

Recently, various applications of dielectric elastomers working with fluids have appeared, such as the artificial heart working with blood, soft robots working under water, energy harvesting systems working with ocean waves, and so on. To analyze this kind of FSI systems is obviously a challenging multiphysics problem, and evidently requires a stable, robust and powerful numerical method to carry out the numerical simulations, with considerations of the complicated electromechanical coupling (EMC) and fluid-structure interaction (FSI) behaviors.

Recent researches in [2-5] have proposed an robust, stable, accurate and efficient numerical method, so called Immersed Smoothed Finite Element Method (IS-FEM), for 2D and 3D FSI problems with largely deformable nonlinear solids placed within incompressible viscous fluid. In this research, a novel numerical method, so called IS-FEM-DE, is proposed, which is based on the main framework of the original IS-FEM. IS-FEM-DE is able to analyze the FSI systems consisting of dielectric elastomers with EMC behaviors. In this method, both of the fluid and solid solvers are proposed in the frame of the gradient/strain smoothing technique and the weakened-weak (W^2) formulations. Gradient Smoothing Method (GSM) [6] is employed as the fluid solver to solve the fluid flows. The dynamic responses of solids are solved using Smoothed Finite Element Methods (S-FEM). To analyze the dynamic responses of DE with EMC behaviors, the semi-explicit dynamics S-FEM proposed in [7, 8] is employed as solid solver. The FSI conditions are imposed using the concept of fictitious fluid and the Lagrangian fictitious fluid meshes introduced in IS-FEM.

Convergence studies demonstrate that the stability of the IS-FEM-DE with the second order spatial convergence property. Numerical examples show the superior capability of the IS-FEM-DE in solving transient fluid flows, and the electromechanical coupling dynamic responses of the dielectric elastomers, which provides a powerful numerical simulation tool for the FSI systems consisting of dielectric elastomers.

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