DEFORMATIONAL ANALYSIS OF HYPERELASTIC BODIES SUBMERGED IN VISCOUS FLUIDS USING A NEW FLUID-STRUCTURE INTERACTION BOUNDARY ELEMENT METHOD FORMULATION

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Abstract

The analysis of elastic bodies submerged in viscous fluids is of great importance in science and engineering applications: interaction of blood flow with elastic veins, vibrations of flexible pipes induced by vorticity, design of peristaltic pumps, hydrodynamics in marine biology.

In general, numerical modeling of fluid-structure interaction problems represents a highly complex task that requires the use of multi-domain mathematical formulations based on constraint coupling equations to ensure the continuity of fundamental variables describing the problem. The use of traditional numerical methods such as the Finite Element Method requires discretization of coupled domains; mesh updating at each step of analysis is needed [1] and solution of large number of equations is unavoidable.

The Boundary Element Method (BEM) is well established for modeling problems in solid mechanics. Unlike traditional domain discretization methods, BEM only requires discretization of the contour of the body under analysis [2]. Thus a significant reduction in computation time is obtained. Also the use of BEM for fluid flow analysis in closed and open domains has been reported in the literature. In such problems, use of discretization domain methods like the Finite Fluid Volume Method requires discretization of irregular fluid domains which could be a cumbersome task.

In this paper a new formulation based entirely on the BEM for the deformational analysis of hyperelastic bodies submerged in incompressible viscous fluids is presented. The BEM formulation presented in [3] is used to modeling the mechanical response of the submerged body. The formulation uses the Total Lagrangian approach so that the boundary and domain integrals are evaluated in the undeformed configuration. Moreover, the BEM formulation reported in [4] is used to modeling incompressible viscous fluid flows. The continuity, Navier-Stokes and energy equations are used for calculation of the flow field. The governing differential equations, in terms of primitive variables, are derived using velocity-pressure-temperature. The calculation of fundamental solutions and solutions tensor is showed. A monolithic fluid-structure formulation is proposed to coupling fluid and solid integral equations. The solution time evolution is performed using the Crank-Nicholson method in conjunction with the Newton-Raphson method for the iterative solution for the equations. Domain integrals involving nonlinear terms in the formulation are treated using the method proposed in [5]. Applications to fluid-interaction problems, which represent good agreements in comparison with the literature, are presented illustrating the potentialities of the proposed methodology.

Key words: Hyperelastic solids, Fluid structure interaction, Viscous fluids, Boundary Element Method, Fluid-Flow, Newtonian fluids, Submerged bodies.

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