

Colloquium

Immersed boundary methods for simulating vesicle dynamics

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摘 要：

Vesicles dynamics in fluid flow has become a quite active research area recently in the communities of soft matter physics and computational fluid mechanics. Indeed, the understanding of vesicle behaviors in fluids might lead to a better knowledge of red blood cells (RBCs) in bloods since they both share some similar mechanical behaviors. For the past years, the vesicle problems have been extensively explored by the classic and small deformation theories, flow experiments, and computer simulations; just to name a few recent ones.

In this talk, we give a simple immersed boundary method to simulate the dynamics of three-dimensional axisymmetric inextensible vesicles in incompressible Navier-Stokes flows. Instead of introducing a Lagrange's multiplier to enforce the vesicle inextensibility constraint, we modify the model by adopting a spring-like tension to make the vesicle boundary nearly inextensible so that solving the unknown tension can be avoided. We also derive the new elastic force from the modified vesicle energy and obtain the exactly same form as the original one. The Fourier spectral approximation is used to represent the interface so we can compute the interfacial geometrical quantities more accurately. With penalization for inextensible constraint, we can simply solve the Navier-Stokes equation by a second-order projection method. Only three elliptic equations are involved in each time step (two for intermediate velocity field and one for pressure) and they can be solved efficiently by some fast solvers. A series of numerical tests on the present scheme have been conducted to illustrate the applicability and reliability of the method. We first perform the accuracy check of interfacial geometrical quantities, and the convergence check for different stiffness numbers as well as fluid variables. Then we study the vesicle dynamics in quiescent flow and in gravity. At last, the shapes of vesicles in Poiseuille flow are investigated in detail to study the effects of reduced volume, the confinement, and the mean flow velocity. The numerical results are shown in good agreement with those obtained in literatures.

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