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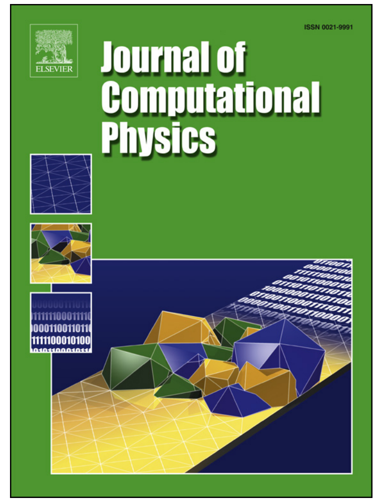

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Interaction problem between fluid and membrane by a consistent direct discretisation approach

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Abstract

Numerical methods for solving the flow around a moving or deforming membrane are developed by employing the ideas of the *direct-discretisation* of the Navier-Stokes equation even in the immediate vicinity of the object surface and *consistent-discretisation* of the pressure Poisson equation with the incompressible velocity field (i.e., consistent-coupling) that incorporates the boundary conditions on the surface to the pressure equation. Comparative study of three different discretisation strategies is carried out to highlight the effect of the consistent and direct discretisations. The validity of the present "consistent direct discretisation" is established through comparisons with the analytical solutions for some fundamental shear-driven 2-D flow fields with a moving membrane of a flat and corrugated geometries. Also, the flows induced by a membrane of circular geometry (i.e., particle) are compared with the reference numerical results under prescribed motion in a stationary fluid as well as lateral migration in a shear flow. A three dimensional problem is presented for an interaction problem between a spherical particle and Taylor-Green vortices, and the result is verified by comparing with the independently-conducted numerical results. Finally, the method is applied to an interaction problem between the fluid and flexible filament showing strong flapping and snapping motions.

Key words:

Discrete-forcing; Immersed boundary; Membrane; Moving boundary; Particle

1 Introduction

The interaction between a fluid and solid object is observed in a variety of problems in industrial applications and biological flows, such as the flows including fibres, solid particles, capsules and biological cells. The modelling of the fluid-object interaction, particularly fluid-mediated multiple-body interaction, is understood as one of the challenging subjects for computational fluid mechanics. For those problems, a fixed-mesh approach is often employed regardless of the object geometry, and the fluid motion is solved based on an Eulerian frame. The fluid-object interface is segmented by the fluid mesh, and each segment immersed in the fluid experiences the fluid force. On the other hand,

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