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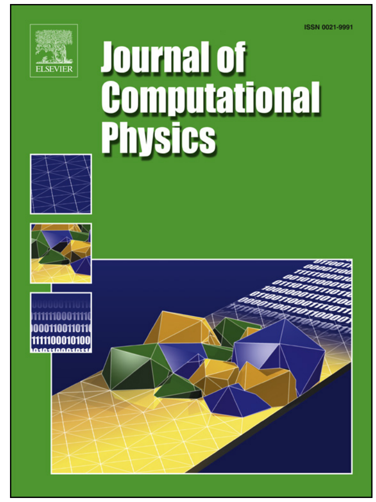

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A pre-conditioned implicit direct forcing based immersed boundary method for incompressible viscous flows

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Abstract

A novel immersed boundary (IB) method based on an implicit direct forcing (IDF) scheme is developed for incompressible viscous flows. The key idea for the present IDF method is to use a block LU decomposition technique in momentum equations with Taylor series expansion to construct the implicit IB forcing in a recurrence form, which imposes more accurate no-slip boundary conditions on the IB surface. To accelerate the IB forcing convergence during the iterative procedure, a pre-conditioner matrix is introduced in the recurrence formulation of the IB forcing. A Jacobi-type parameter is determined in the pre-conditioner matrix by minimizing the Frobenius norm of the matrix function representing the difference between the IB forcing solution matrix and the pre-conditioner matrix. In addition, the pre-conditioning parameter is restricted due to the numerical stability in the recurrence formulation. Consequently, the present pre-conditioned IDF (PIDF) enables accurate calculation of the IB forcing within a few iterations. We perform numerical simulations of two-dimensional flows around a circular cylinder and three-dimensional flows around a sphere for low and moderate Reynolds numbers. The result shows that PIDF yields a better imposition of no-slip boundary conditions on the IB surfaces for low Reynolds number with a fairly larger time step than IB methods with different direct forcing schemes due to the implicit treatment of the diffusion term for determining the IB forcing. Finally, we demonstrate the robustness of the present PIDF scheme by numerical simulations of flow around a circular array of cylinders, flows around a falling sphere, and two sedimenting spheres in gravity.

Keywords: Immersed boundary method; Implicit direct forcing; Pre-conditioning; Incompressible flows

1. Introduction

In many engineering applications, it is important to accurately predict flows near solid objects with complex geometries. One method for simulating the flows around these objects uses a body-conformal grid

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