Computational Fluid Dynamic (CFD) method to simulate complex-structured soft-body locomotion using OpenFOAM

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Abstract

Analysis of the locomotion of a structure or an organism moving in a fluid field is a multi-disciplinary subject involving hydrodynamics, structure analysis, biological engineering, and medical diagnosis. Because of their highly non-linear characteristics, fluid-related problems cannot be fully solved with analytical methods. Even though soft-body motions can be described using certain advanced approaches such as the user-defined function (UDF) in FLUENT (ANSYS) and the user defined subroutine (USDFLD) in ABAQUS, there are still many challenges, especially the computational cost. For conventional CFD methods, the topological coordinates' transformation from the geometry-based local coordinate to the domain-based global coordinate in every time step of a dynamic process makes the computation extremely expensive and inaccurate. To overcome this issue, several alternative CFD methods have been explored and developed. A widely used example is the Immersed Boundary Method (IBM), which separates the fluid domain mesh from the mesh of moving objects. This strategy could make the domain mesh fixed, which would reduce the computation of the re-meshing process and the corresponding computation of coordinate transformation. Some commercial software programs have implemented the IBM module, but their limitations remain, for example, the IBM module in CFX (ANSYS) can only handle rigid body motion (six-DOF problems). In this study, codes to simulate soft-body motion were developed. These are modified based on the original codes from Foam-extend 3.2 (OpenFOAM, an open-source software) where only the rigid body motion of IBM has been implemented. For applications, firstly, normal cylindrical models were tested using IBM of OpenFOAM and verified with FLUENT (ANSYS). Then, models of harmonic wave motion and rotation were tested and compared to benchmark results from OpenFOAM, FLUENT, and CFX. Finally, the simulation results of harmonic wave motion using OpenFOAM were compared with the analytical models of narrow slender swimming motion reported in Taylor [1]. All these comparisons showed that the Immersed Boundary Method (IBM) using open-source codes can work effectively in modeling and in solving problems of fluid-structural interactions. For future work, this code will be used to simulate the complex-structured soft-body motion of Polychaeta (a paddle-aided harmonic body wave motion).

Keywords: CFD, soft-body, Immersed Boundary Method, open-source

References

[1] G. Taylor, (1952), Analysis of the Swimming of Long and Narrow Animals, in *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences*, pp. 158-183.