A Versatile Immersed Boundary Method for Biological Flows with Application to Fish Pectoral-Fin Hydrodynamics

[1]Rajat Mittal*, [1]Haibo Dong, [1]Meliha Bozkurttas, [2]Fady Najjar, [1]Alfred Loebbeck and [1]Abel Vargas

[1]*Mechanical and Aerospace Engineering*
The George Washington University

[2]*Center for Simulation of Advanced Rockets*
University of Illinois at Urbana Champaign

The last decade has seen a tremendous rise in the popularity of immersed boundary methods (Mittal & Iaccarino 2005) The primary factor driving this is the relative ease with which this methodology allows researchers to develop computational models of flows with complex geometries and/or moving boundaries. Immersed boundary solvers have been employed successfully for simulating biological flows, physiological flows, flow-induced vibration and complex turbulent flows. The key feature of the immersed boundary method is that simulations with complex boundaries can be carried out on stationary, body non-conformal Cartesian grids. This approach eliminates the need for complicated re-meshing algorithms that are usually employed with conventional Lagrangian body-conformal methods. These methods provide a unique capability for simulating flows with complex moving boundaries and as such, are ideally suited for simulation of bio-hydrodynamic flows.

In our presentation we will describe a versatile Cartesian grid-based immersed–boundary method which is especially well suited for biological flows. Boundary condition treatment for solid/flexible bodies and membranous structures like fish fins and insect wings, as well as comprehensive validation of the solver will be described in the presentation. The solver is being used for a detailed examination of fin pectoral fin hydrodynamics and results from numerical simulations of this configuration along with a novel POD analysis of fish fin kinematics and hydrodynamics will be presented. Based on the simulations and companion experiments conducted by Lauder et al. (2005) we will provide a comprehensive analysis of our current understanding of the key hydrodynamic mechanisms in this flow. Finally we present some results from ongoing work in full-body analysis of human and dolphin swimming and insect flight.

References

Mittal, R. and Iaccarino, G. (2005) Immersed Boundary Methods , *Annual Review of Fluid Mechanics,* Vol 37.

Lauder, G., Madden, P., Hunter, I., Tangorra, J., Davidson, N., Proctor, L., Mittal, R., Dong, H., Bozkurttas, M., "Design and Performance of a Fish Fin-Like Propulsor for AUVs", *Proceedings of 14th International Symposium on Unmanned Untethered Submersible Technology* (UUST), Durham, New Hampshire, 2005.

* Corresponding author
mittal@gwu.edu
Ph. 202 994-9394