Numerical simulations of flow around intense appendage movements for aquatic propulsion

Asimina Kazakidi[a,*]

[a]*Department of Biomedical Engineering, University of Strathclyde, Glasgow, UK*

Abstract

The flow dynamics around elongated slender geometries undergoing time- dependent intense motions, which apply to cases of appendage-based aquatic locomotion, is of considerable importance for understanding the energetics of these motions and for exploiting energy-efficient strategies to apply in novel propulsion designs. The difficulty in simulating such flows lies in the solution accuracy. The use of fixed-grid methods has been the gold standard for such flows, in which a moving (immersed) boundary is defined on a stationary domain; thus, these methods are capable of handling arbitrarily large motions and deformations and allow effective transient solutions of complex fluid problems. Within the immersed-boundary framework, we propose implementations for medium and extreme motions, ensuring stability and accuracy of transient motion results. The movements investigated are based on kinematic models extracted both from available three-dimensional motion reconstruction data of animal swimming and the literature. This study includes a series of specific geometries and motions, which entail parametric studies of performance and propulsive efficiency. The author would like to thank J.A. Ekaterinaris & D.P. Tsakiris for their support and insightful discussions, and F. Sotiropoulos & D. Angelidis for providing the CURVIB code. It is acknowledged that the results of this research have been achieved using the H2020 PRACE-4IP DECI-13 resources (ICARUS project, 13DECI0256) on Beskow cluster based at KTH Royal Institute of Technology, Sweden.

Keywords: Immersed boundary method, numerical simulations, aquatic locomotion

---

*Corresponding Author
Email address: asimina.kazakidi@strath.ac.uk (Asimina Kazakidi)

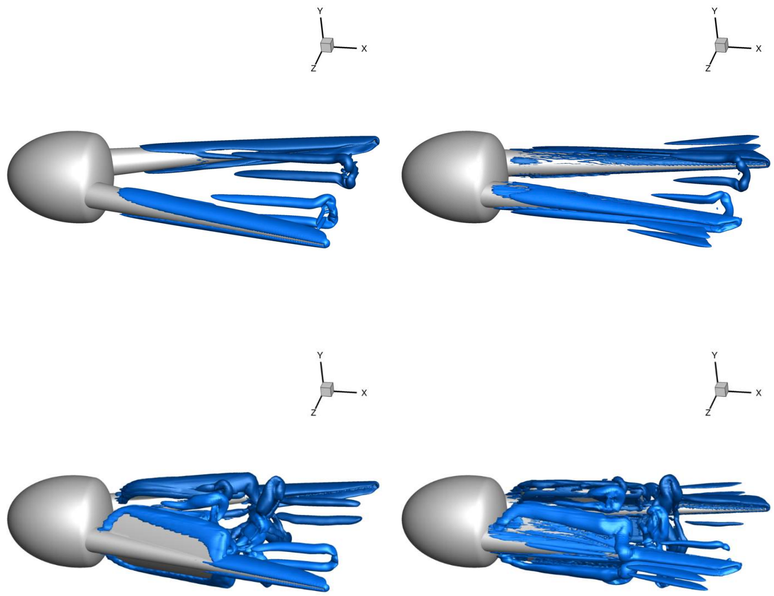

Figure 1: Instantaneous vortical patterns (colored in blue) in the wake of an appendage-based propulsive system, with (top) conical appendages and (bottom) side flaps, using a high-fidelity parallel Immersed Boundary method. Low-thrust (left) and high-thrust (right) motion strokes.

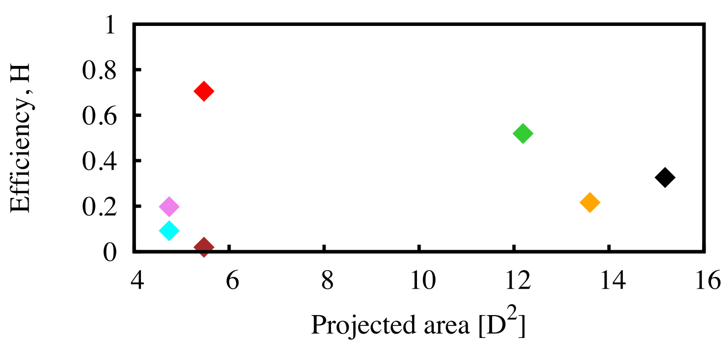

Figure 2: Evaluation of efficiency, H, for an appendage-based propulsive system using several morphologies, plotted against the respective projected area. The conical appendages (red diamond) and side flaps (green diamond) have the highest efficiency.