ICCES, 2025, vol.33, no.2

Tech Science Press

DOI: 10.32604/icces.2025.011601

PROCEEDINGS

A Numerical Analysis of Dorsal and Anal Fins in Zebrafish C-Turn Maneuvering

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ABSTRACT

The dorsal and anal fins play crucial roles in aquatic propulsion, serving as auxiliary structures that enhance fish mobility. This study investigates the functional contributions of these fins during zebrafish C-turn maneuvers through computational simulations. We reconstructed the three-dimensional morphology of zebrafish based on experimental data, with particular attention to dorsal and anal fin modeling. Using the open-source immersed boundary method code IBAMR, we simulated self-propelled C-turn motions to elucidate the fins' impact on turning performance. Comparative analysis of C-turns with varying rotational amplitudes revealed that dorsal and anal fins effectively suppress boundary layer diffusion along the fish body. The fins' trailing edges generate posterior body vortices (PBVs) that interact with the caudal fin, thereby enhancing leading-edge vortices (LEVs) strength. Additionally, these fins moderate peak angular velocity during turns, resulting in smoother maneuvering. Fin size significantly influences translational and rotational performance: smaller fins marginally increase final translational velocity, while larger fins enhance translational performance at the expense of rotational capability. This demonstrates that dorsal and anal fins effectively increase the height of the caudal peduncle, thereby boosting thrust generation during C-turns. As lightweight, adjustable-area structures, these fins can optimize thrust enhancement and drag reduction according to propulsion requirements, ultimately improving overall maneuvering performance in C-turns. This study advances our understanding of auxiliary fin functions in fish propulsion and maneuvering, providing valuable insights for the design of bio-inspired underwater vehicles.

KEYWORDS

C-turn; CFD; zebrafish; dorsal and anal fins

Acknowledgement: We extend our sincere gratitude to Professor Boyce Griffith and Amneet Bhalla for their expert guidance and technical insights on the IBAMR open-source software.

Funding Statement: This study received funding from the National Natural Science Foundation of China (Grant Nos. 12172355).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.