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Numerical Study of Flapping-Wing Flight of Hummingbird Hawkmoth during Hovering: Longitudinal Dynamics

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Abstract : In recent decades, flapping wing aerodynamics has attracted great interest. Understanding the physics of biological flyers such as birds and insects can help improve the performance of micro air vehicles. The present research focuses on the aerodynamics of insect-like flapping wing flight with the approach of numerical computation. Insect model of hawkmoth is adopted in the numerical study with rigid wing assumption currently. The numerical model integrates the computational fluid dynamics of the flow and active control of wing kinematics to achieve stable flight. The computation grid is a hybrid consisting of background Cartesian nodes and clouds of mesh-free grids around immersed boundaries. The generalized finite difference method is used in conjunction with single value decomposition (SVD-GFD) in computational fluid dynamics solver to study the dynamics of a free hovering hummingbird hawkmoth. The longitudinal dynamics of the hovering flight is governed by three control parameters, i.e., wing plane angle, mean positional angle and wing beating frequency. In present work, a PID controller works out the appropriate control parameters with the insect motion as input. The controller is adjusted to acquire desired maneuvering of the insect flight. The numerical scheme in present study is proven to be accurate and stable to simulate the flight of the hummingbird hawkmoth, which has relatively high Reynolds number. The PID controller is responsive to provide feedback to the wing kinematics during the hovering flight. The simulated hovering flight agrees well with the real insect flight. The present numerical study offers a promising route to investigate the free flight aerodynamics of insects, which could overcome some of the limitations of experiments.

Keywords : aerodynamics, flight control, computational fluid dynamics (CFD), flapping-wing flight
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