A Computational Study on the Fluid-Structure Interaction Mechanism in Insect Flapping Wings

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Abstract: This study shows that some of important characteristic motions in insect flapping wings can be created by the fluid-structure interaction. A lumped flexibility model is used to describe the flexibilities in insect's wings. A three-dimensional finite element method for the fluid-structure interaction analyzes the behaviors of the model wing, the surrounding fluid, and their interaction, where the dynamic similarity law for the fluid-structure interaction is used to incorporate actual insect data. This finite element method uses the projection and parallel computation algorithms, which perform the systematic parametric study efficiently. The elastic recoil and the modes in the path of the wing tip such as the figure-eight shown in the present wing's passivity are the vibration phenomena caused by the interaction with the surrounding fluid excited by the wing's flapping. Therefore, they are modulated by the flexibility and flapping parameters. Furthermore, they have significant effects on the behavior of the leading-edge vortex, and change the magnitude of the aerodynamic force acting on the wing. It follows form these results that one possible explanation for the controllability of the lift force in actual insect can be summarized as follows: The fluid-structure interaction causes the characteristic motions in the flexible flapping wing. The insect modulates them using the flexibility and flapping parameters to change the lift force. Compared to previous approaches that prescribe entire wing motions in micro air vehicles, this fluid-structure interaction mechanism will reduce the electromechanical complexity of the flapping device.

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