2012 Special Program in Applied Mathematics and Applied Mechanics

Three-dimension vortex dominated flow around low-aspect-ratio wings: simulation and flow control

2012 - 03 - 06 (Tue.)
15:00 - 17:00
308, Mathematics Research Center Building (ori. New Math. Bldg.)

Biological flyers and swimmers use low-aspect-ratio (low-AR) wings or fins to achieve efficient and agile locomotion. Low-AR wings are also used in the designs of small-scale surveillance vehicles called the Micro Air Vehicles (MAVs). The unique flight conditions for these animals or vehicles often force their wings to be at high angles of attack. In contract to the high-AR wings on conventional aircraft, flows around the low AR-wings in post-stall situations are not well understood. Such flows are three-dimensional due to the tip effects and unsteady due to the large-scale vortices that form in the wake.

In this work, three-dimensional flows around low-AR wings in translation are numerically investigated with the immersed boundary projection method. Flows around moving or deforming bodies of arbitrary shapes with fluid-structure interaction can be simulated using this solver. This study highlights the unsteadiness generated by the wake vortices behind various low-AR wings over a wide range of angles of attack at low Reynolds numbers. The formation and evolution of the leading-edge, trailing-edge and tip vortices are visualized in detail to provide insights into the wake dynamics. We also study the aerodynamic forces on the wing due to the unsteady vortices and observed that certain arrangements of vortices provide increase in lift on the wing.

Furthermore, active flow control is considered for the purpose of lift enhancement on the wing by modifying the three-dimensional dynamics of the wake vortices. The flow control strategy takes inspiration from flapping wing flyers that use the leading-edge vortices to achieve enhanced lift. This approach exploits flow separation and is different from the conventional control efforts that focus on flow reattachment. Successful control setups that achieve lift enhancement by a factor of two in post-stall flows for low-AR wings will be presented. Effort to perform feedback control to sustain high lift in a stable manner will also be discussed.