Unsteady low-Re flow around translating and pitching low-AR flat plates

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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 unmanned air vehicles. The unique flight conditions for these animals or vehicles often force their wings to be at high angles of attack. Flows in such cases are three-dimensional and unsteady due to the large-scale vortices that form in the wake. In this work, three-dimensional flows around low-AR flat-plate wings in translation and pitching are numerically investigated with the immersed boundary projection method. This study highlights wake vortex dynamics 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 studied. We also examine the aerodynamic forces on the wing due to the unsteady vortices and observed that certain arrangements of vortices provide increase in lift with active flow control. The flow control strategy takes inspiration from flapping wing flyers that use the leading-edge vortices to achieve lift enhancement. This approach exploits flow separation and is different from the conventional control efforts that focus on flow reattachment. Successful control setups that achieve lift increase by a factor of two in post-stall flows for low-AR wings will be presented. We will also show some recent work on modeling the unsteady aerodynamic forces for wings undergoing large-amplitude maneuvers. Towards the end of the talk, a brief overview of the research efforts undertaken by the Taira research group in the areas of unsteady aerodynamics, flow control, hydrodynamics stability analysis, and computational fluid dynamics will be presented.

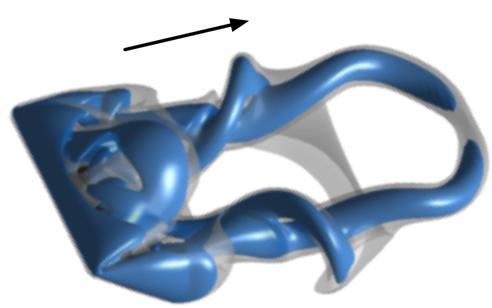

Figure: wake vortices behind a low-aspect-ratio wing.