Aerodynamic Characteristics of Flapping Motion in Hover

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The aim of the present study is to understand the aerodynamics phenomena and the vortex topology of the highly unsteady flapping motion by both numerical and experimental solutions. Instead of the use of real insect/bird wing geometries and motions which are highly complex and difficult to imitate by an exact modeling, a simplified model is used to understand the unsteady aerodynamics and vortex formation during the different phase of the flapping motion. The flow is assumed to be laminar with the Reynolds number of 1,000. The experimental results obtained by the laser sheet visualization and the Particle Image Velocimetry (PIV) techniques are used for the phenomenological analysis of the flow. The vortex dynamics is put in evidence and explained with the use of different tools. Vortex identification from PIV measurements is performed by considering velocity magnitude, streamlines, second invariant of velocity gradient (Q-criteria), vorticity contours and Eulerian accelerations.

During a period, three types of vortices are generated: Leading Edge Vortex (LEV) at the leading edge of the airfoil, Translational Vortex (TV) at the trailing edge of the airfoil and Rotational Stopping Vortex (RSV) similarly at the trailing edge of the airfoil. The LEV and TV are the vortices generated during the translation of the airfoil and RSV is generated due to the rotation of the airfoil and detach from the airfoil at the return.

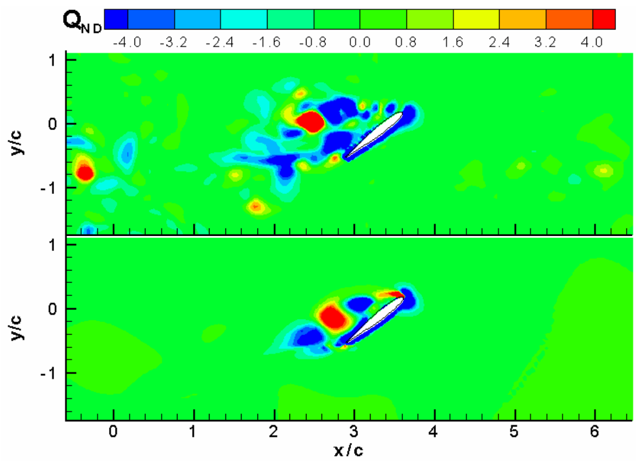

Fig. 1 Instantaneous non-dimensional Q contours at t=0.28 from PIV measurements (top) and DNS results (bottom)*

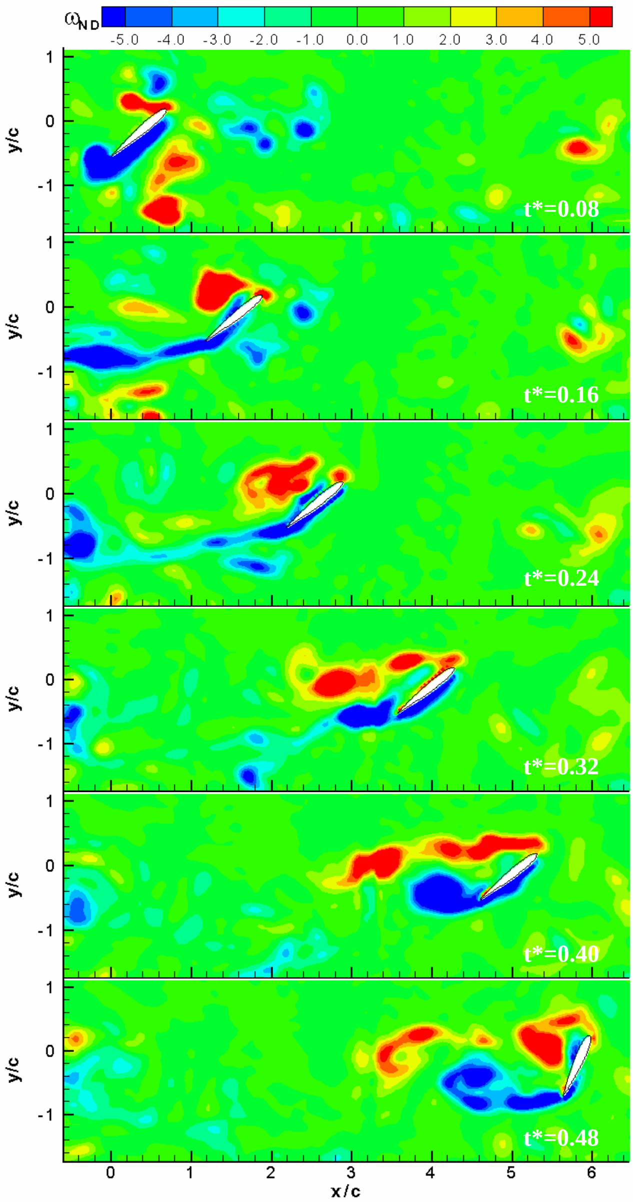

Fig. 2 Instantaneous non-dimensional vorticity contours from PIV measurements

The more energetical vortices are highly visible both in experimental visualizations and numerical simulations and these are the ones which influence more the aerodynamic forces on the airfoil. The trace of the rotation stays visible in experimental visualizations while there is a quick diffusion in numerical simulations. Experimental results give more complicated topology compared to numerical simulations.