Direct numerical simulations of plunging airfoils wakes using spectral/hp element method.

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Plunging airfoils are investigated for applications such as Micro-Air Vehicles (MAVs) and bird and fish like propulsion. Plunging or flapping wings can provide more propulsive efficiency than that of fixed wings, especially at small to moderate Reynolds numbers, where the MAVs (due to their small size) operate. Furthermore, it has been observed that birds and insects rely on detaching and separating vortices resulting from the flapping motion to create higher lift and thrust. Thus, understanding the flow over plunging airfoils and its dependence to varying the governing parametrs is of great interest. The Reynolds number, the frequency and amplitude of the plunge motion are the most important parameters to characterize the aerodynamics of plunging airfoils and their wakes. In this contribution the unsteady flow over a plunging 2D airfoil is simulated using a high-order numerical method associated with a moving frame of reference technique. Most numerical methods used in the scientific community are second-order accurate in time and space, we use here a high-order method to obtain more accurate and high resolution data that are used to characterize the boundary-layer over the airfoil and the wake patterns. The results are presented in terms of vorticity countours (particularly at the boundary-layer and the wake region), time averaged horizontal velocity and time series of the force coefficients. As predicted by theory and experiments, three wake patterns are identified, namely : drag producing wake (Karman Street), thrust producing wake (reversed Karman Street) and neutral wake. The mean incidence investigated is $\overline{\alpha} = 0^\circ$ and Reynolds number $4500 \leq Re \leq 10^4$. Furthermore, a non-zero mean incidence is considered $\overline{\alpha} = 12^\circ$ and the contribution of the leading-edge shedding to the lift and thrust production is discussed. The transition from a drag producing wake, to a neutral, and a thrust producing wake is observed when increasing the plunge frequency (at constant amplitude) and the amplitude (at constant frequency). These results are in accordance with previsous published experimental and computational investigations at $\overline{\alpha} = 0$. Moreover, we investigate the case where $\overline{\alpha} = 12$, varying the plunge amplitude frequency, and characterizing the wake patterns.