ANALYSIS OF LIFT COEFFICIENT AND TRAILING VORTICES PROPERTIES AT LOW REYNOLDS NUMBER WITH SPANWISE DEFORMATION

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Abstract We have experimentally studied the effects of spanwise wing deformation on the lift coefficient and wingtip vortices (wingtip vortex, lift coefficient, PIV2D, wing model deformation).

Wing aerodynamic loads lead to significant spanwise deformations at low Reynolds number regimes where Micro air vehicles (MAVs) and unmanned aerial vehicles (UAVs) operate. The flow behaviour at this regime is particularly complex, and it is influenced strongly by a laminar separation bubble (LSB) formed in the suction side of the wing profiles. Thus, any subtle variation of experimental conditions or wing geometry affects wing forces and flow structures.

We have measured the hydrodynamic forces and velocity fields of the trailing vortices generated by three different wing models in a towing water tank at several angles of attack before reaching the stall. We performed all the experiments at a constant chord-based Reynolds number, $Re = 20 \times 10^3$. The models are NACA 0012 rigid wings with semi-aspect (semi-span length to chord) ratio $sAR = 2$ and have an imposed spanwise deformation replicating the experimental data reported by [1]. Specifically, one model is non-deformed (ND), and the other two have a maximum tip deflection of $\delta = 2\%$ (intermediate deformation, ID) and $\delta = 4.5\%$ (large deformation, LD). Our results elucidate that for the smaller angles of attack (e.g. $\alpha = 4°$), spanwise deformation decreases the lift generated by the models, but at higher angles (e.g. $\alpha = 8°$ or $9°$) the deformation increases the lift, see the comparison between ND and LD in Fig. 1.

We also used two-dimensional particle image velocimetry (PIV2D) in a plane perpendicular to the free-stream direction to obtain velocity fields of trailing vortices at different axial distances. The parameters of the theoretical models of Batchelor [2] and Moore & Saffman [3] were computed and used to corroborate that we did not find any variation of the vortex structure with the wingspan deformation. Furthermore, we employed an empirical formula recently proposed by [4] to relate the lift measurements with the circulation of the trailing vortices, computed from PIV measurements, observing a direct relationship between the two.

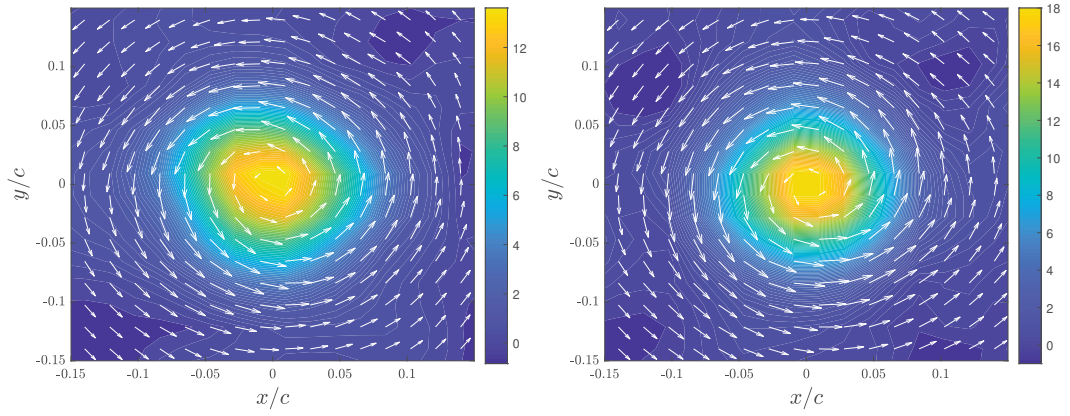

Figure 1. Velocity and vorticity fields around the vortex core at z/c =3, $\alpha = 9°$, and δ = 0% (ND, left) and 4.5% (LD, right) for $Re = 20 \times 10^3$.

References

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