Characterization of the flow around an auto-rotating winged seed

G. Arranz[*], M. Uhlmann[†], M. García-Villalba[*] and O. Flores[*]

Direct numerical simulations of the auto-rotation of a winged-seed model are performed at Reynolds number between 80 and 240. The simulations are performed by coupling the Navier-Stokes equations with the Newton-Euler equations of the seed. Thus, due to this coupling, when the Reynolds number is changed, both the flow around the seed and the kinematics of the seed change.

Fig. **??**(a) depicts the flow around the auto-rotating seed at $Re = 240$ (although a similar flow is obtained for the lower Re investigated) by means of the Q criterion. Three main vortical structures can be observed, a wing tip vortex, a vortex shed at the nut and a leading edge vortex (LEV) above the wing of the seed (dark grey surface in Fig. **??**a). In this presentation, we will focus on the study of the latter.

By using a reference frame attached to the seed, where the flow can be assumed to be steady, we explore the variation of the relative velocity, relative vorticity and pressure due to the change of Re. Specially, we relate the appearance of a spanwise flow beneath the LEV with Coriolis and centrifugal accelerations (Fig. **??**b); and we observe that the vorticity inside the LEV is directly related to the angular velocity of the seed, which also varies with Re. Additionally, we study the stabilization of the leading edge vortex (LEV). In this regard, three different hypotheses for LEV stability, namely, vorticity transport along the LEV, viscous effects and fictitious accelerations, are analysed in the range $Re = [80 - 240]$.

This work was supported by grant DPI2016-76151-C2-2-R (AEI/FEDER).

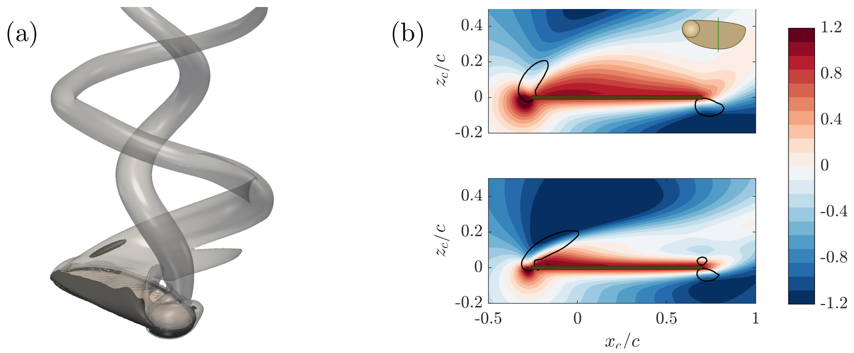

Figure 1: (a) Iso-surfaces of the Q-criterion for $Re = 240$. Dark grey surface is 16 times more intense that light grey surfaces. (b) Contours of the spanwise component of the fictitious accelerations at the mid-span for $Re = 80$ (top figure) and $Re = 240$ (bottom figure). Black lines correspond to the intersection of the dark grey iso-surface in Fig. **??**(a). The accelerations are normalized with the maximum chord of the wing seed, and the angular velocity for each Re.

[*]Dep. Bioingineering and Aerospace Engineering, Universidad Carlos III de Madrid, Av. de la Universidad 30, Leganés, Spain

[†]Inst. for Hydromechanics, Karlsruhe Institute of Technology, Karlsruhe, Germany