On the competition between leading-edge-vortex and tip-vortex growth for a pitching plate

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The interaction between leading-edge and tip-vortex development on a low aspect ratio and nominally two-dimensional rectangular flat plate has been investigated. Simultaneous to force measurements, three-dimensional Particle Tracking Velocimetry (3D-PTV) was used to characterize the instantaneous flow field on the suction side of the plate. When examining the instantaneous spanwise circulation distribution for the two plates it is determined that the spanwise velocity induced by the tip vortex has the effect of reducing the leading-edge-vortex circulation near the tip of the plate. Iso-surfaces of the spanwise and tip vorticity, as shown in Figure 1, at various time steps after the beginning of motion help identify the similarities between the vortical structures between both slow and fast pitch-up motions, indicating that the vortex formation process is proportional to dimensionless time and not the instantaneous pitch angle. Furthermore, vortex tilting and stretching terms are examined and found to be small in the early stages of leading-edge-vortex and tip-vortex development, suggesting that at these early times such structures grow independently of one another. Later on in the vortex development vortex tilting is present such that the leading-edge vortex is reoriented into the tip vortex. At the same time the leading-edge vortex erupts at the inboard section through the presence of negative vortex stretching.

Fig. 1 Qualitative comparison between spanwise (red, dark) and tip (yellow, light) vorticity for the slow (top) and fast (bottom) pitching motion of the low aspect ratio plate at non-dimensional times of 3, 4 and 5 from left to right. Oncoming flow is in the positive x-direction.