The wing-tip vortex kinematics of a supercritical airfoil at moderate angle of attack

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For decades, the wingtip has been recognized as a source of a complex system of flow structures, which include wing-tip vortices, shear layers and wake entrainment. These flow structures are of significant interest in both academia and industry due to their high-intensity noise emissions. In the current study, we present both the mean and instantaneous characteristics of the wing-tip flow structures at an angle of attack of $\alpha = 10^\circ$ and a tunnel speed corresponding to a Reynolds number $Re_c = 1.0 \times 10^6$. The experiment was conducted in the anechoic wind tunnel at the University of Toronto Institute for Aerospace Studies. The flow field was measured using stereo-Particle Image Velocimetry (stereo-PIV). Additionally, oil flow visualization was employed to trace the location of the wing-tip flow structures. The oil deposits on the surface highlight the separation lines and provide insight into the local flow directions on the surface.
Mean flow structures measured using the stereo-PIV and surface oil flow visualization are shown in Figure 1. The stereo-PIV results show the existence of three independent tip vortices that grow in size as they travel downstream. The oil flow visualization visualizes the separation lines form along the path of the tip vortices. These vortices co-rotate along a common axis to form a helical flow structure.

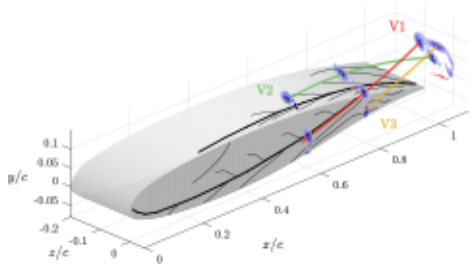

Figure 1: The mean wing-tip flow structures measured through the sPIV and the surface oil flow visualizations.

In the presentation, the kinematics of the wing-tip vortices and the difference between the primary, secondary and tertiary vortex will be discussed in more detail using more sophisticated analysis methods, such as the Proper Orthogonal Decomposition (POD). A deeper look into the instantaneous snapshots of the flow structures will be done to elucidate the key differences in the three wing-tip vortices. The repercussion to the wing-tip noise generation will also be discussed.

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