Master thesis and internship[BR]- Master's thesis : Simulation of a wingtip vortex flow with Linear Eddie Viscosity turbulence models at Re = 4.6E6 and Re = 1.2E6[BR]- Integration Internship

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Simulation of a wingtip vortex flow with Linear Eddie Viscosity turbulence models at Re = 4.6E6 and Re = 1.2E6

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This work studies the accuracy of Linear Eddie Viscosity models on the prediction of wingtip vortex flow. The geometry selected for the study is a NACA-0012 half wing mounted at the wall, with a rounded end cap and trailing edge, inclined by 10° at its quarter chord.

Computations of the flow were conducted using the open source software SU2. Two turbulence closures were investigated: the Negative Spalart-Allmaras and the Menter's Shear Stress Transport models. The flow was considered at two Reynolds numbers : $Re = 4.3 \text{ x } 10^6$ and $Re = 1.2 \text{ x } 10^6$. To study the models' accuracy, the initial objective of the work was to produce high-fidelity LES data using the software ARGO provided by Cenaero. However, due to the setup of the simulations and the computing time requirements, we fail to obtain LES simulations of the entire wing. Therefore, the computed flow is compared against the experimental and numerical data found in the literature.

The results showed that LEVM could characterize the main vortical structures' topology and surface flow quantities. However, they fail to predict the evolution of the mean quantities on the vortex core. This divergence between the numerical simulations and the experimental results was associated with the eddie viscosity, which caused a diffusion of the mean quantities, and the models' assumptions, which cannot correctly represent the Reynold stress and strain rate tensors misalignment observed in the experimental data.

Although we could not fulfill the project's initial objective, we were still able to provide indications of possible future work based on comparing the RANS results with the reference experimental and numerical data.

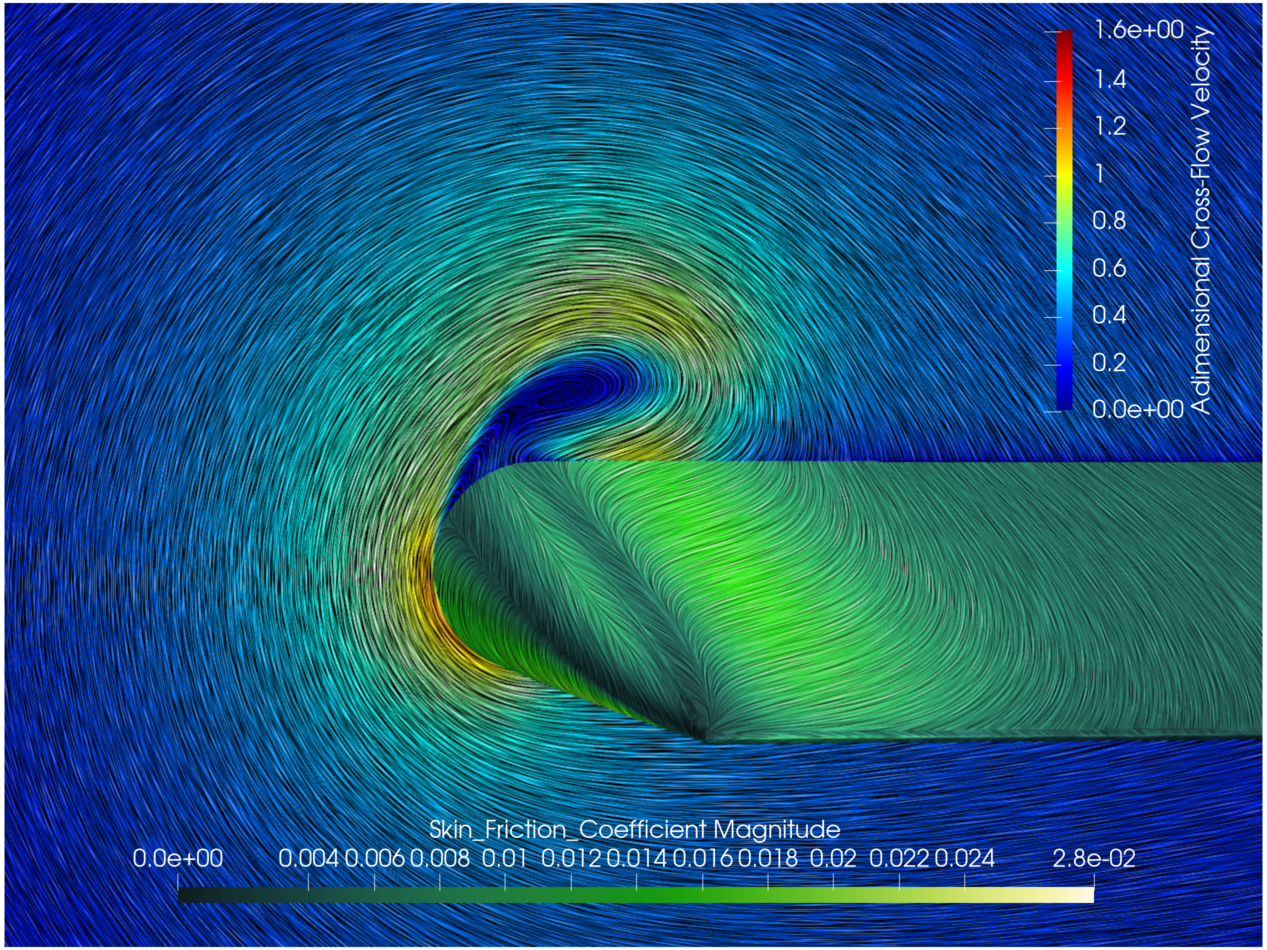


Figura 1: Wing surface skin friction lines combined with the xz cutting plane cross-flow lines at $x/c = -0.2$. Both the cross-flow and the skin friction vector field were visualized with LIC vector field visualization in the open source software PARAVIEW. The skin friction lines are colored by the skin friction coefficient c_f, while the cross-flow lines are colored by the adimensional cross-flow velocity U_{cf}/U_{ref}.

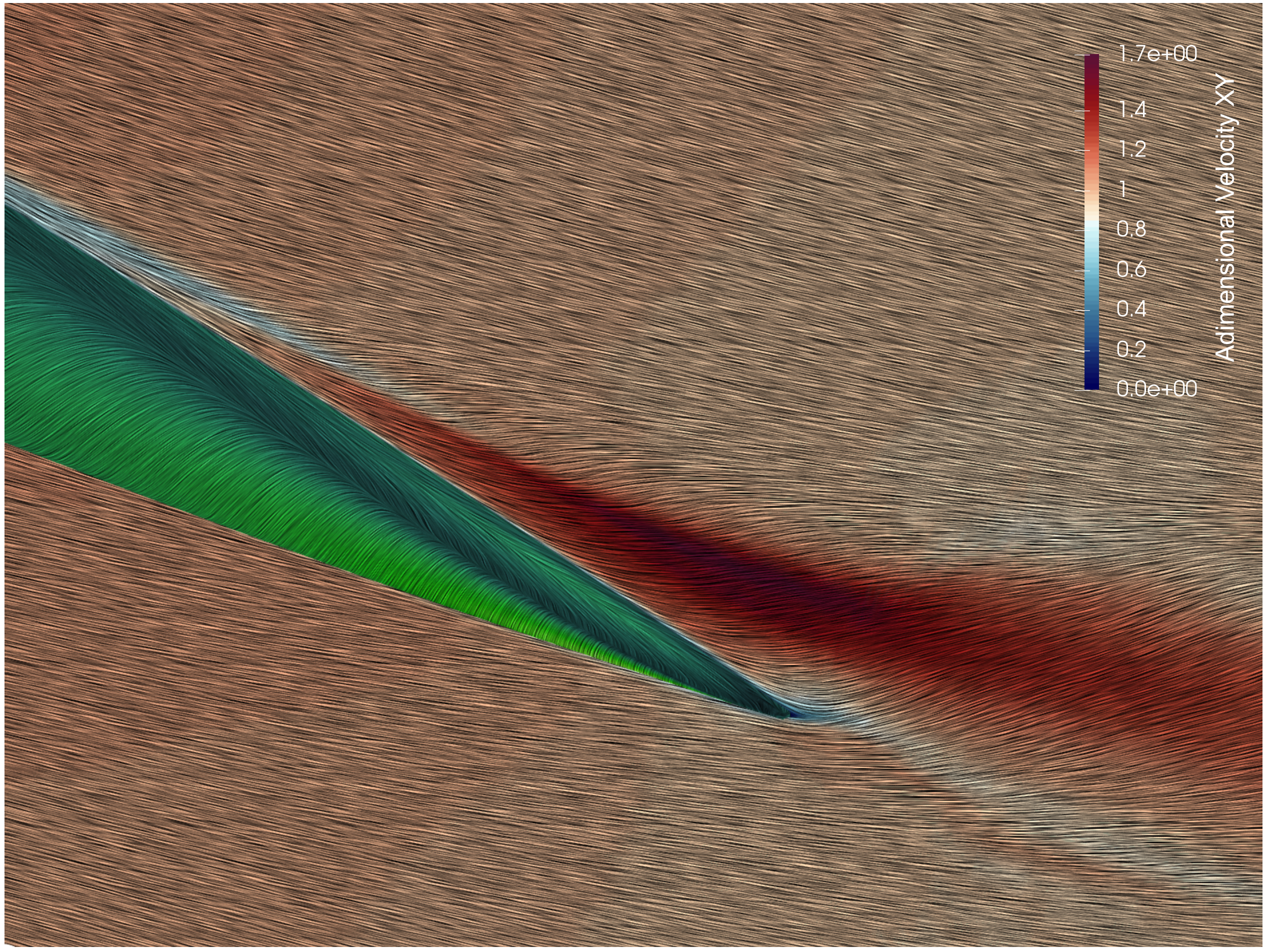


Figura 2: Skin friction lines on the wing surface combined with the velocity field projected in the xy cutting plane at $z/c = -0.005$. The skin friction lines are colored by the skin friction coefficient c_f, while the velocity lines are colored by the adimensional velocity projected in the XY plane U_{xy}/U_{ref}. The velocity and skin friction field were visualized with LIC vector field visualization in the open source software PARAVIEW.

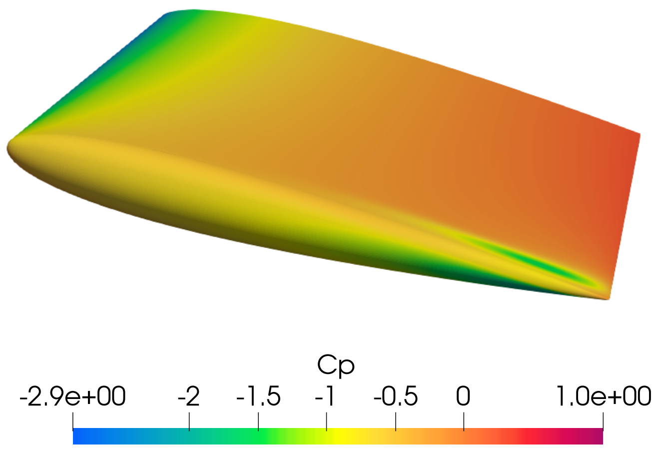


Figura 3: Surface static pressure coefficient.

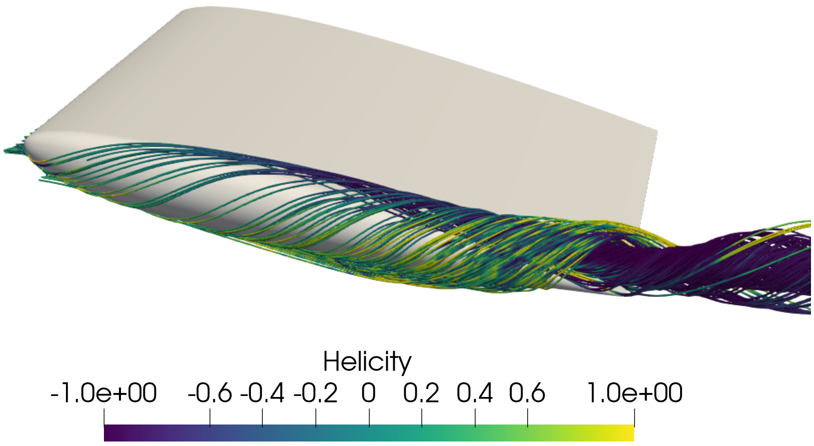
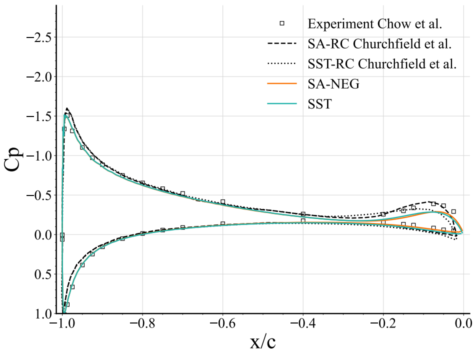
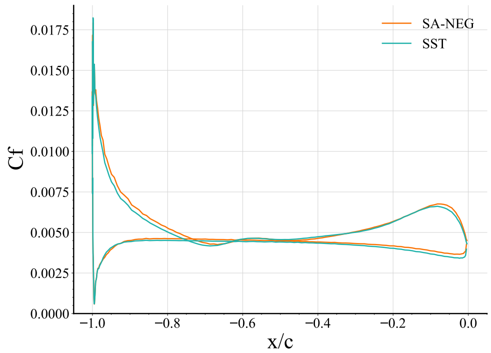


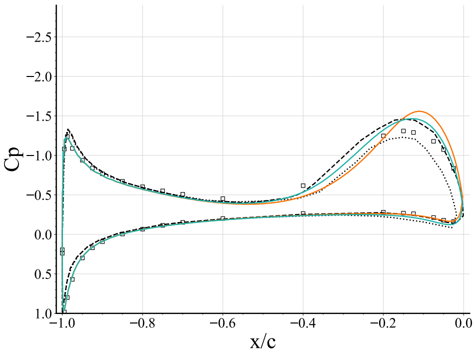
Figura 4: Vortex visualization using three-dimensional streamlines extracted from the velocity field. The streamlines are colored by the normalized helicity, defined as inner dot product of velocity and vorticity vectors, $H = (\boldsymbol{U} \cdot \boldsymbol{\omega})/(|\boldsymbol{U}||\boldsymbol{\omega}|)$. This physically represents the angle between the velocity and vorticity fields, and it helps to visualize the vortex core (characterized by the alignment of the two vectors). In this case, one can notice that the vortex core, in dark blue, is placed on the lower rear part of the wing tip directly above the suction side.



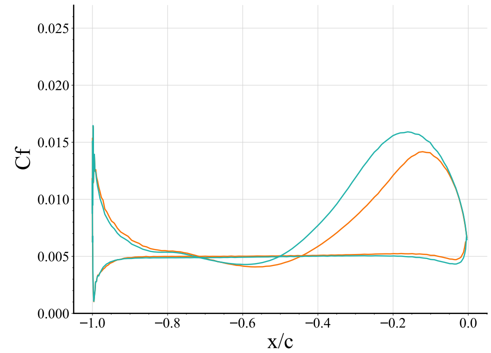
(a) $z/c = -0.065$



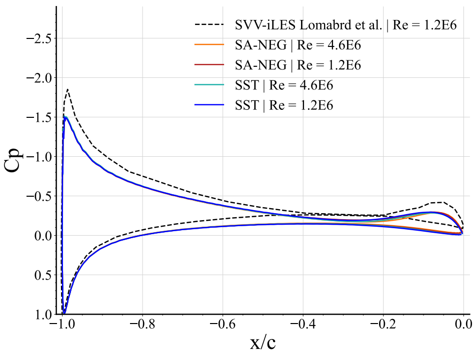
(b) $z/c = -0.065$



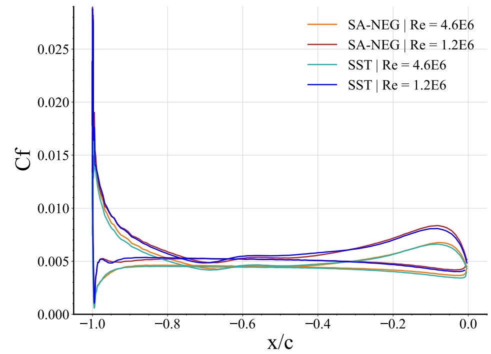
(c) $z/c = -0.023$



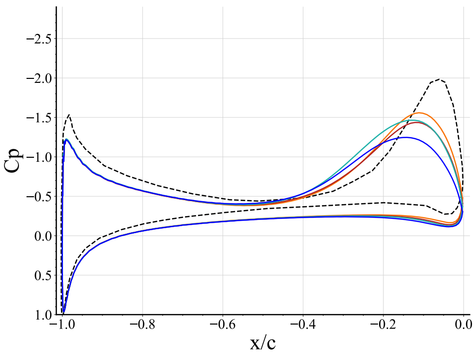
(d) $z/c = -0.023$



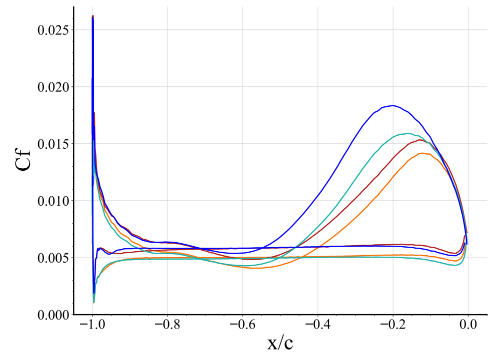
(e) $z/c = -0.065$



(f) $z/c = -0.065$



(g) $x/c = -0.023$



(h) $z/c = -0.023$

Figura 5: Stream-wise skin friction coefficient magnitude C_f and static pressure coefficient C_p distributions at two span-wise locations.

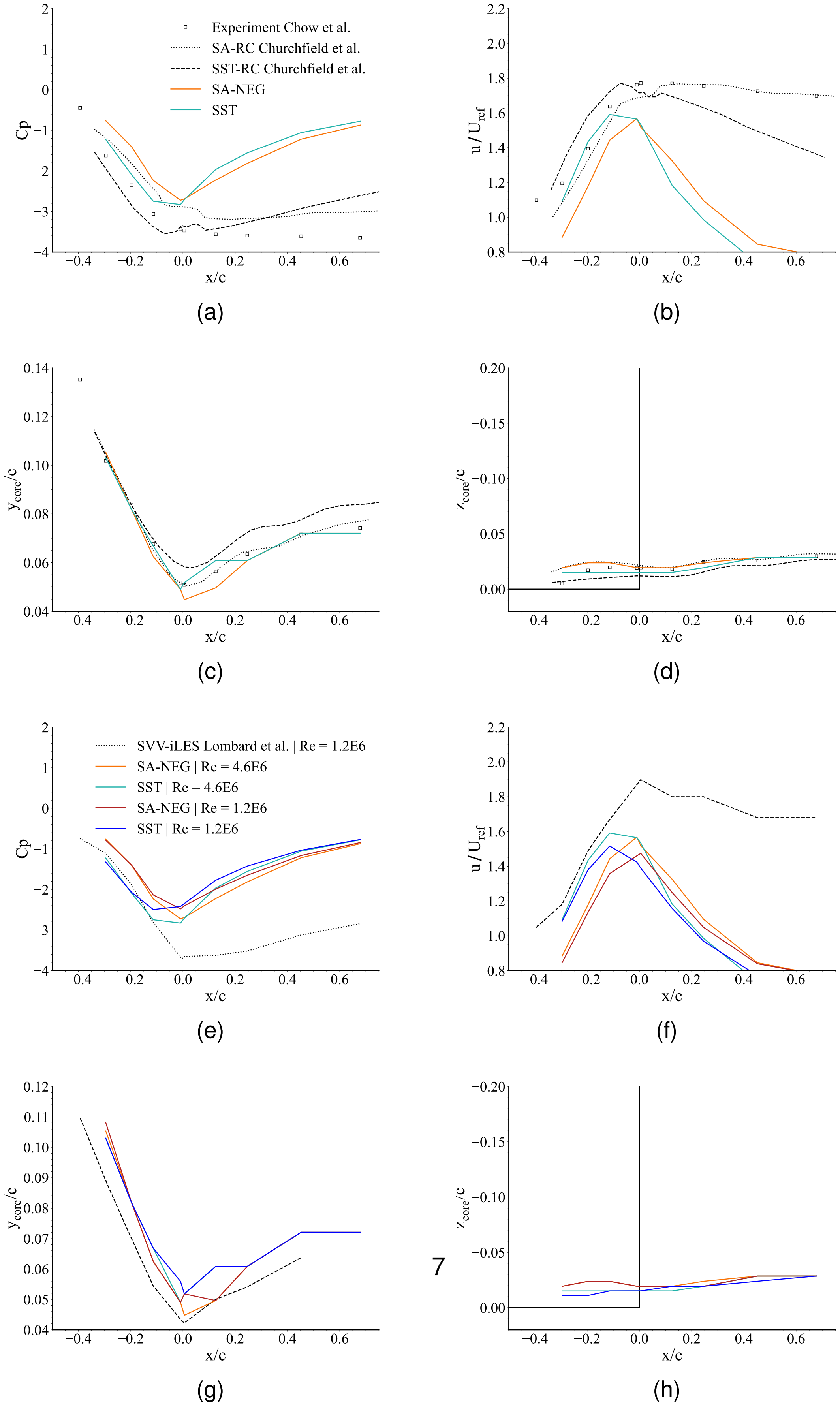


Figura 6: Flow means quantities evolution along the cortex centerline. In (d) and (h), the continuous black line illustrates the wing position.