6 Conclusions and Suggestions

6.1 Conclusions

A numerical simulation was carried out on the rear wing of the Formula Student car owned by PUC-Rio, using steady RANS equations along with two turbulence models. Moreover, an automatic mesh generation methodology provided by the OpenFoam utility, snappyHexMesh, was evaluated regarding the compromise between the final mesh size and numerical errors. The following conclusions can be drawn from the results of this study.

- The study reveled that the grids generated, using the snappyHexMesh utility have flaws that may influence the simulations results. Among the flaws found in the grid are: the difficulty in generating near-wall layers at steep changes in the surface curvature and the problem to control the first layer height. However, it was possible to overcome this shortcomings increasing the refinement in the regions of larger curvature and in the end, the results seemed to be unaffected by these small issues.
- The results showed that using elements with relatively high aspect ratio improved the results, decreasing the numerical diffusion in the near-wall region. More refinement was needed in the far field downstream of the wing in order to avoid numerical diffusion in the transitions from one level of refinement to other. This was also the case along the tip vortex path in order to better catch the gradients there.
- In spite of the difficulty to control the refinement parameters near the wall, generating the grid only by setting up its parameters decreased the total time needed to generate the grid compared with the time it would take to do it with a traditional method. Moreover, the total amount of elements in the unstructured grid was smaller due to the possibility of using an exponential local refinement. This would certainly translate to less labor hours and less processing time.
- The post-processing tools allowed the visualization of two vortices at the edges of the end plate and a central one growing from the junction

of the wing and the end plate, at the suction surface. As expected, a horseshoe vortex was also observed on the end plate just in front of the leading edge. Moreover, local recirculation zones were observed for both angles of attack extending through the wingspan at the suction surface. The effects of these structures were identified in the pressure distribution over the wing surface as a local delay of boundary layer separation and as a peak in the pressure due to the recirculation bubbles.

– The aforementioned three-dimensional behavior was more intense near the wing tip, while in the middle of the wing the flow was found more uniform and almost two-dimensional. This behavior was noted to be intensified as the angle of attack increases, due to the intensification of the tip vortex energy and the increase of boundary-layer separation.

– Through the detailed information made available by the numerical simulation, it was possible to gain a deeper understanding into the physics of a single-element wing and into the effects the diverse structures formed around the wing can produce on its overall performance.

6.2 Suggestions for Future Works

As part of future works, some of the studies proposed below will be useful to take advantage of the good features showed by this methodology, as well as validate even more its suitability for the analysis and development of aerodynamic devices.

– Studying different airfoils.

– Studying the flow around non-rectangular wings.

– Studying the influence of the end plates geometry.

– Using LES or DES methods to solve the flow around wings.

– Studying the influence of devices aimed at harnessing kinetic energy from tip vortices.