Computational Characterization of vortexes generated by Low-Profile Vortex Generators


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Abstract

Flow separation control and the energy losses associated with the boundary layer (BL) have emerged as a key point in certain industrial fluid dynamics applications. The flow separation from a continuous surface is governed by the adverse pressure gradient and the viscosity. If the flow must remain attached to the wall, the stream should have enough energy to overcome the adverse pressure gradient, the viscous dissipation along the flow path and the energy loss caused by the modification in momentum. If the loss is such that further advancement of the fluid is no longer possible, then the flow separates from the surface.

Vortex generators (VGs) are passive devices to control flow which are able to change the motion performance of the fluid in the BL region. VGs are small vanes not aligned with the oncoming flow and they act by exchanging momentum from the distant flow region to the wall-closed inner region. Triangular and rectangular conventional VGs have been implemented onto wings of airplanes for flow control to efficiently improve mixing of the BL and transfer momentum nearby the wall by delaying or suppressing the flow separation. In the experimental work performed by Velte [1] and the associated simulations carried out by Fernandez-Gamiz et al. [2] and Urkiola et al. [3] demonstrated that the primary vortex produced by a rectangular VG mounted on a flat plate showed self-similarity for axial and azimuthal velocities. In most applications, VGs are designed with their height $h$ similar to the local BL thickness $\delta$ and mounted normal to the surface with an incident angle to the flow to produce streamwise vortices. However, the residual drag related to these $\delta$-scale conventional VGs might be relatively large in some flow-control application.

The generation of streamwise vortices by means of the implementation of vane-type devices with reduced height is a simple method to enhance their efficiency. Lin et al. [4] proved that when decreasing the height of standard VGs to a value lower than the local BL thickness, the momentum transfer keeps being large enough to avoid or delay flow separation downstream of the VGs. These so-called low-profile VGs were mounted on multi-element high-lift airfoils with the aim of controlling the flow separation on the flap. Ashill et al. [5] in a conceptual and experimental study showed a successful delay of the shock-induced separation on a transonic profile by mounting Sub Boundary Layer Vortex Generators (SBLVG). According to Lin [6], the implementation of these low-profile VG devices could be considered as a feasible option to be implemented when the flow-separation positions are relatively fixed and the vanes can be implemented upstream relatively nearly the flow separation.

The main goal of this work is to characterize the size of the primary vortex generated by a single VG on a flat plate by OpenFOAM CFD code. This is performed by estimating the half-life radius of the vortex and comparing it with experimental results. Consequently, numerical simulations based on the simpleFoam solver have been carried out using Reynolds Average Navier-Stokes equations at Re=27000 based on the local BL thickness where the VG was placed. A total of twenty cases have been considered. The set-up consist of a single vortex generator VG implemented on a flat plate with angles of attack with respect to the oncoming flow of $\beta=10^\circ$, $15^\circ$, $18^\circ$, $20^\circ$ and device heights respect to the local BL $h/\delta=0.2$, 0.4, 0.6, 0.8, 1.2.
