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Mitigation of the Laminar Separation Bubble using Active Vortex Generators

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Overview

The purpose of this research is to determine if rectangular, counter-rotating vortex generators (VGs) mitigate the laminar separation bubble (LSB) at a low Reynold's number (60,000) (Fig. 1). Particle image velocimetry (PIV) is used (Fig. 2) to gather velocity contours of mean flow fields data that are used to observe the LSB for two VG cases: VG-1 optimized for α= 8° and VG-2 optimized for α= 10°.

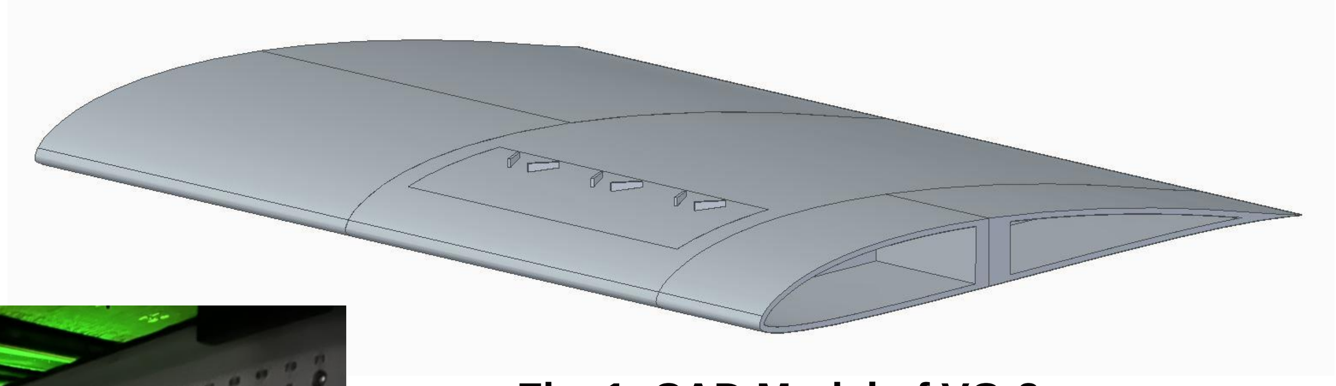

Fig. 1: CAD Model of VG-2

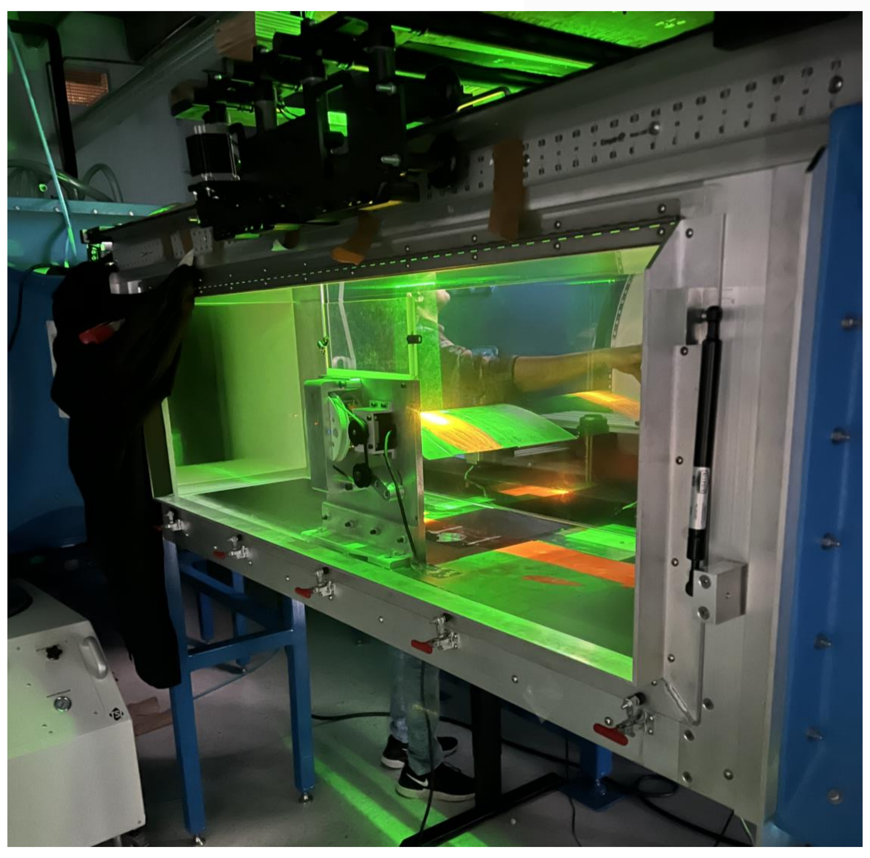

Fig. 2: Experimental Setup

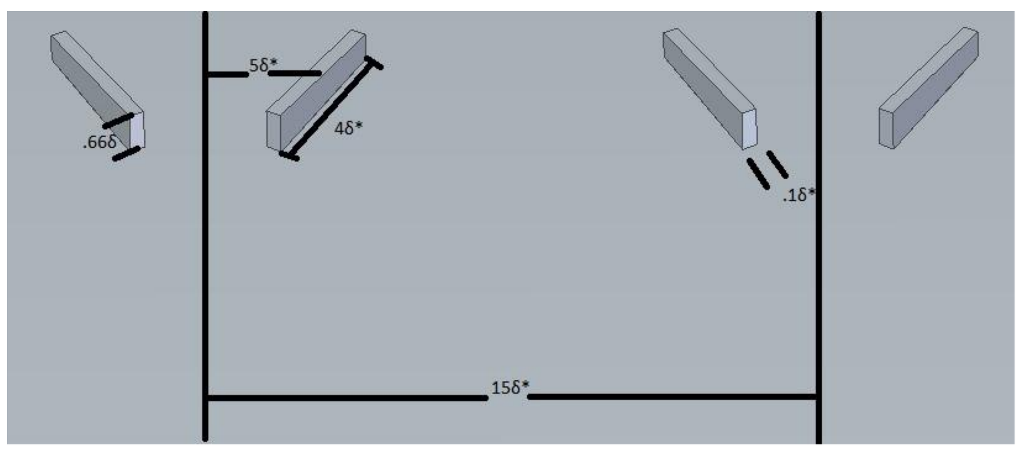

Fig. 3: Optimized Vortex Generator Dimensions

Conceptual Framework

Vortex generators are used to increase flow attachment by transferring energy from the freestream to the boundary layer [2]. The LSB occurs when attached laminar airflow traverses an adverse pressure gradient, causing the flow to become unattached [3]. It is the energy added to the boundary layer from the VGs that prevents the laminar flow from separating, thereby preventing LSB formation, which in turn adds lift and reduces LSB induced pressure drag [4]. This study made use of dimensions optimized for maximum energy transfer to the flow from the boundary layer (Fig. 3) to mitigate the LSB, without introducing additional pressure drag from exceedingly robust geometry [1] [2].

Key Findings

The time-averaged velocity contours (Fig. 4) that examined the effect of the VG cases at 20% chord on an SD-7032 airfoil showed that both VG cases were effective in mitigating the LSB. Cases (a) and (b) show the presence of the LSB on the baseline airfoil. Case (c) shortened the length of the LSB seen in (a) quite significantly, although a residual LSB formed approximately 25mm downstream from the VG. Case (d) eliminated the LSB observed in case (b), though the boundary layer at the trailing edge is significantly taller than the optimized case, (f), possibly indicating additional pressure drag. Cases (e) and (f) demonstrated a significant amount of trailing edge separation caused by the larger geometry of the 10° case. Regardless of residual separations, it is likely that lift was increased for all VG cases as the LSB was noticeably mitigated.

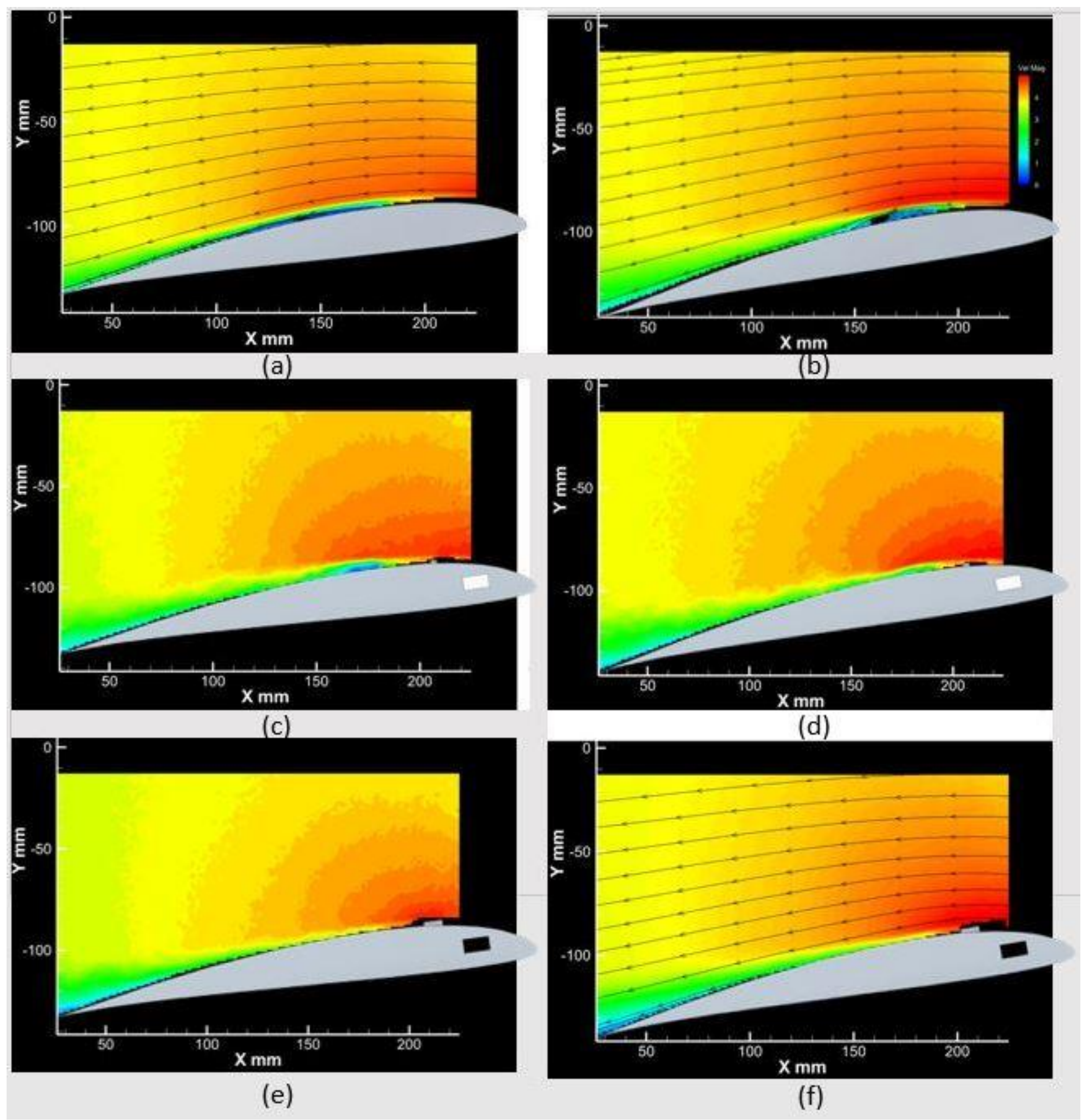

Fig. 4: Velocity Contours for Re= $6.0 * 10^4$ with (a) No VG, α= 8°, (b) No VG, α= 10°, (c) VG-1, α= 8°, (d) VG-1, α= 10°, (e) VG-2, α= 8°, and (f) VG-2 α= 10°,

Impact

Active vortex generators can be used on high cruise efficiency airfoils to optimize performance at low Reynold's number, high angle of attack conditions present during takeoff and landing [4].

References

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