BBAA VI International Colloquium on:
Bluff Bodies Aerodynamics & Applications
Milano, Italy, July, 20-24 2008

VORTEX GENERATORS EFFECT ON LOW REYNOLDS NUMBER AIRFOILS IN TURBULENT FLOW

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Keywords: Turbulent flow, Low Reynolds numbers, Airfoil, Vortex generators.

Abstract *The main purpose of this work is to study, in turbulent flow conditions, the effect of triangular vortex generators placed on the upper surface of an airfoil on its aerodynamic coefficients. In the experiments, different configurations of vortex generators have been studied. Their positions respect to the leading edge and their incidence angle have been varied. A low Reynolds number airfoil Eppler 387 modified was used. The tests were performed in a boundary layer wind tunnel using a two components aerodynamic balance and flow visualization systems.*

1 INTRODUCTION

A vortex generator is taller than the boundary layer thickness of the airfoil. Its effect is the production of small vortices that generate changes in the flow pattern. Specifically, changes in the circulation around the airfoil, energization of the boundary layer, modifications on the three dimensional characteristics of the flow and channeling of the incident flow in order to generate higher circulation and then lift force are observed.

The effect produced by these devices depends strongly on their position and on their geometrical configuration. These characteristics are chosen in function of the desired effect. An improvement of the airfoil performance for a certain flight condition, dilation or smoothening of the stall condition or an enhancement of the lift or drag forces are all possible desired effects [1]. Both of these devices could be placed on the upper or lower surface of the airfoil permanently of only when they become necessary –retractable option-. Their activation could be manual, during take-off or approaching maneuvers, or automatic when stall condition is reached or during a particular maneuver when a given angle of attack is reached, all this depending on the sort of device and the desired effects.

For very high angles of attack, the main flow is detached from the airfoil upper surface and stall condition takes place. As the angle of attack continues increasing the drag coefficient increases too, while the lift coefficient either increases or remains the same.

The lift and drag coefficients behavior will be studied for different angles of attack with or without vortex generators. Also, different positions of vortex generators with different incidence angles will be tested [2].
Through this work we intend to offer further data about the behavior of an Eppler 387 modified airfoil, with vortex generators placed on its upper surface for a given incident flow condition. All tests will be performed in a boundary layer wind tunnel with specific turbulent flow conditions.

2 METHODOLOGY

The tested model consists of a 42cm chord and 80cm span wing with an Eppler 387 modified airfoil added with triangular vortex generators Fig. (1).

The wind tunnel test section where the tests were performed is 7.5m long, 1.4m wide and 1m tall. For the characterization of the turbulence a hot wire constant temperature anemometer was used. A two component aerodynamic balance with a charge cell with double Wheatstone bridge was used. The signal was acquired with signal conditioners and amplifiers Vishay series 2310, connected to a PC. The vortex generators are 40mm long, 10mm tall and 0.5mm thick. In order to produce, as close as possible, a two dimensional flow configuration over the wing model two panels were place at both sides of the model during the test. Once the desired turbulence characteristics were established and the incoming flow velocity fixed according to the desired Reynolds number, the test consisted in measuring the lift and drag forces for each given angle of attack. The previous sequence was repeated for the wing without any devices and then for the wing with the vortex generators placed at 10% and 20% the chord length from the leading edge at 0, 10 and 20 degrees from the incoming flow direction.

During the test, temperature, wind velocity, vertical and horizontal loads were measured for different angles of attack [3]. Loads were acquired at a frequency of 500Hz. Their values were temperature-corrected and the lift and drag coefficients were calculated following well known formulas. A wind tunnel correction was also performed [4]. All the tests were made at a velocity of 8m/s and a Reynolds number of 300000 with the desired turbulence characteristics.

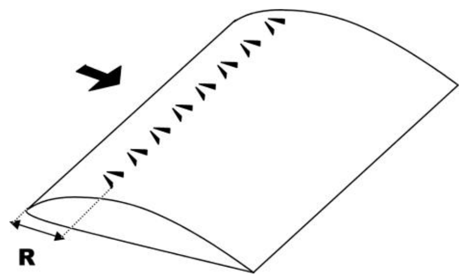

Figure 1. Vortex generators configuration

R = vortex generators location, measured from the leading edge of the airfoil (10% to 20% of the chord).

3 RESULTS

The experiments were carried out for a determined turbulent flow, characterized for its mean and fluctuating velocity components, turbulence spatial and temporal scales and power density spectrum. With all of these variables we characterized the flow.

We assumed the validity of frozen flow Taylor´s hypothesis. The turbulence intensity in the U component is 3.691% and in the V component is 1.608%.

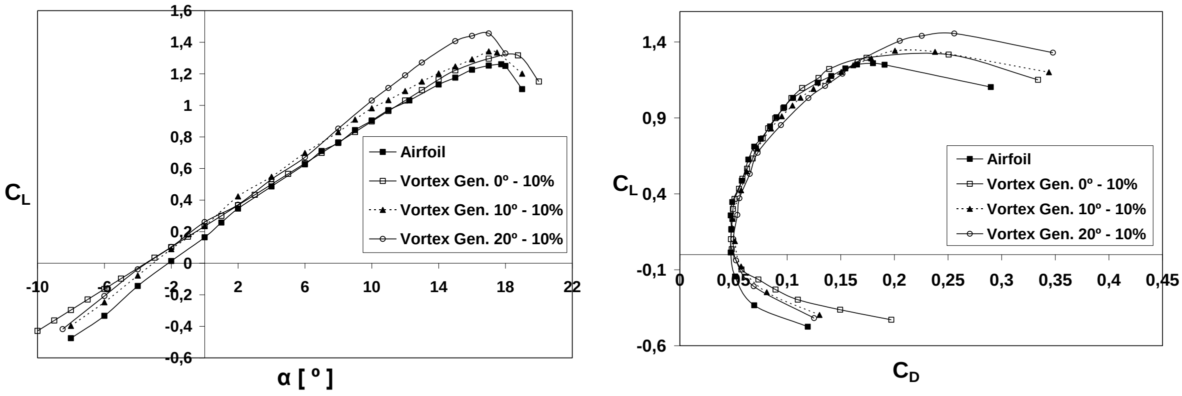

Figure 2

In Fig. (2) lift coefficient vs. the angle of attack is shown for the wing without any devices and for the vortex generators placed at 10% the chord, for angles of attack of 0deg, 10deg and 20deg. Practically, no variation in the slope is produced by the vortex generators. No variation in the zero lift angle of attack is detected. However, a change in the maximum lift coefficient is detected. As the vortex generators attack angle increases, the C_{Lmax} value increases reaching a maximum value corresponding to a vortex generator angle of attack of 20deg, placed on the upper surface of the airfoil. In Fig. (2) the drag coefficient is plotted against the lift coefficient. No significative drag or C_{Do} variations are observed.

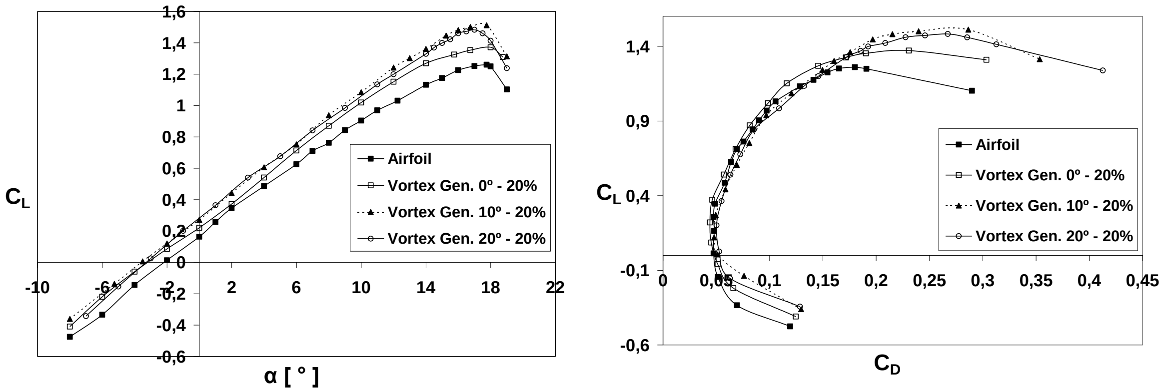

Figure 3

This Fig. (3) shows the lift coefficient vs. angle of attack corresponding to the vortex generators placed at 20% of the chord length from the leading edge. No change is observed in the curves slope, however, the zero lift angle of attack and the C_{Lmax} vary, repeating the tendency observed for the vortex generators at 10% the chord. In other words, the C_{Lmax} increases as the angle of attack of the vortex generators increases.

In the polar curve corresponding to the 20% chord position (Fig. (3)) no important difference can be appreciated in the values of lift and C_{Do}. The lowest drag is observed for the vortex generator placed at 20% the chord with an angle of attack of 0deg. Fig. (3) shows the similar behavior of the vortex generators placed at 20% the chord in relation to those placed at 10% the chord. As the angle of attack increases the drag is higher in the devices with higher angle of attack.

Below we show a comparative table between the airfoil without any devices and the airfoil with the vortex generators. For each case, the values of C_{Lmax} and its corresponding angle of attack, and C_{Do} are shown. It can be observed no major change in the stall angles.

Device	α	CL max	Cdo
Airfoil	17.75º	1.26	0.0475
Vortex Gen. 0º -10%	18.75º	1.31	0.0485
Vortex Gen. 10º-10%	17º	1.34	0.0581
Vortex Gen. 20º-10%	17º	1.45	0.0501
Vortex Gen. 0º -20%	18º	1.37	0.0481
Vortex Gen. 10º-20%	17.75º	1.51	0.0518
Vortex Gen. 20º-20%	17º	1.48	0.0531

Device	E max	α (E max)	α (CL = 0)	CL (α = 0)
Airfoil	10.24	7º	-2	0.163
Vortex Gen. 0º -10%	10.08	10º	-3.5	0.236
Vortex Gen. 10º-10%	9.76	8º	-3.25	0.236
Vortex Gen. 20º-10%	9.23	6º	-3.5	0.261
Vortex Gen. 0º -20%	10.68	8º	-3.25	0.221
Vortex Gen. 10º-20%	9.68	8º	-3.5	0.271
Vortex Gen. 20º-20%	9.86	7º	-3.25	0.269

Table 1

Table 1 shows the comparative values for the different devices describing the maximum efficiency and their corresponding angle of attack, the zero lift angle of the airfoil and the value of the C_L for zero angle of attack.

From the table we could deduce that using a vortex generator with 0deg of angle of attack placed at 10% the chord from the leading edge, the value of C_{Lmax} increases 4%. Even more, if the generator is placed at an angle of attack of 10deg, C_{Lmax} increases 6.3%, and if it is placed at an angle of 20deg, C_{Lmax} increases 15%.

For the cases with the generators placed at 20% of the chord, C_{Lmax} increases 8.7% for 0 deg angle of attack, 19.8% for 10 deg, and 17.4% for 20 deg.

4 CONCLUSIONS

Higher values of C_{Lmax} can be obtained using different configurations of vortex generator devices on wing airfoils. Different values of C_{Lmax} are observed for vortex generators placed at different angles of attack respect to the free stream flow direction [5].

The results indicate that the vortex generators must generate a flow around them similar to that produced by a Delta wing, promoting a disorder in the boundary layer, in such a way that the C_{Lmax} results increased at the same time that the stall angle of attack decreases minimally or stays constant. It is observed, as well, that in all the cases the stall is smooth. The curve's slope increases a little or is moved to the left as if other passive flow control device, instead of turbulators, like a fowler flap were acting.

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