AN EXPERIMENTAL STUDY ON DRAG REDUCTION OVER AN AIRFOIL

[1]Srinivasa Rao T,[2]B. EswarKumar Bandi,[3]Dakshinamurthy I, [4]Lovaraju Pinnam
[124]Professor
[1]Mechanical Engg Dept,[2,3,4]Aerospace Engg Dept
[1]VVIT, Nambur, India, [2,3,4]LBRCE, Mylavaram,India

Abstract: **Flow control over an airfoil is very important to increase the lift to drag ratio by delaying the stall. There were many flow controlling techniques over an airfoil available in the literature. In the present study, we have made an aerodynamic modification over an airfoil called trailing edge serrations. In this study, NACA 0015 airfoil is used for conducting the wind tunnel tests. Wind tunnel tests have been conducted on NACA 0015 airfoil with and without trailing edge serrations. These tests were conducted at various test-section velocities of 15m/s, 20m/s, 25 m/s and 30 m/s for 0º, 3º, 6º, 9º, and 12º angles of attack (AoA). The tests were conducted for aerodynamic force calculations (Lift and Drag forces) and pressure distributions as well. The aerodynamics forces were measured using 3-Component External Wind Tunnel Balance. These tests were conducted in a low-speed wind tunnel.**

***Index Terms*–Airfoil, Trailing edge serrations, Drag Reduction, Wind tunnel.**

I. **Introduction:** The importance and possibilities of viscous drag reduction were first seriously identified in the late 1930s, primarily as a result of two developments: successful drag `clean-up' efforts which minimized pressure drag, thereby enhancing the importance of (residual) viscous drag, and the realization. There were many studies related to drag reduction over bodies and especially drag reduction on airfoil becomes very important as it is one of the main components of aircrafts to generate the lift force over it. Xiao Liu et al, studied the aerodynamic performance of airfoils with leading and trailing-edge serrations. He concluded that the trailing- and leading-edge serrations significantly change the aerodynamic performance of the airfoil. The results shown that the level of changes depends greatly on the type the airfoil as well as the geometrical details of the serrations. It is observed in trailing edge serrations case the choose serration can significantly reduce the aerodynamic lift of airfoil and stall properties of the airfoil do not change considerably. H.A.Alawadhi et al, showed the effect of vortices formation from triangular serrations which decrease the upper surface boundary layer when serrations are placed at the lower surface leading edge. Paul T.Soderman et al (1972), studied the aerodynamic effect of leading edge serrations on a two-dimensional airfoil was studied to determine the change in flow field around the model. The leading-edge serrations were effective in reducing separated flow on the model. However, the results are not directly applicable to two-dimensional airfoils since the end plates did not maintain two-dimensional flow over the model. Separated flow progressed inboard from the end plates with increased angle of attack. The serrations delayed the onset of separated flow to higher angles of attack and increased maximum lift and angle of attack for maximum lift of the model. S. Brennan et al (2002) studied the aerodynamic characteristics of airfoils with serration and without serrations. Mathieu Gruber et al studied the effect of serrations on noise reduction. It was found that saw tooth serrations at leading edge significantly reduces the noise. Stefan Oerlemans et al found that the blade modifications of a wind turbine had no adverse effect on their aerodynamic performances.

II. Experimental set-up and procedure

A wind tunnel is a device designed to generate air flows of various speeds through a test section. Wind tunnels are typically used in aerodynamic research to analyze the behavior of flows under varying conditions, both within channels and over solid surfaces. Aerodynamics can use the controlled environment of the wind tunnel to measure flow conditions and forces on models of aircraft as they are being designed. Being able to collect diagnostic information from models allows engineers to inexpensively designs for aerodynamic performance without building numerous fully-functional prototypes. The wind tunnel line diagram is shown in Figure.1

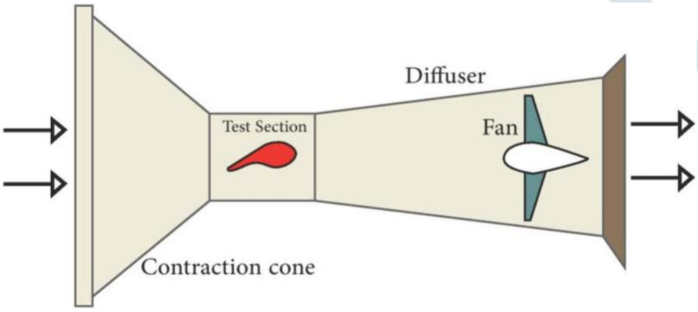


Figure 1. Schematic diagram of Wind tunnel

Wind tunnel experiments were conducted on NACA0015 airfoil with and without trailing edge serrations. These models are shown in Figure 2. Experiments were conducted on these models for pressure distributions as well as lift and drag acting on these models.

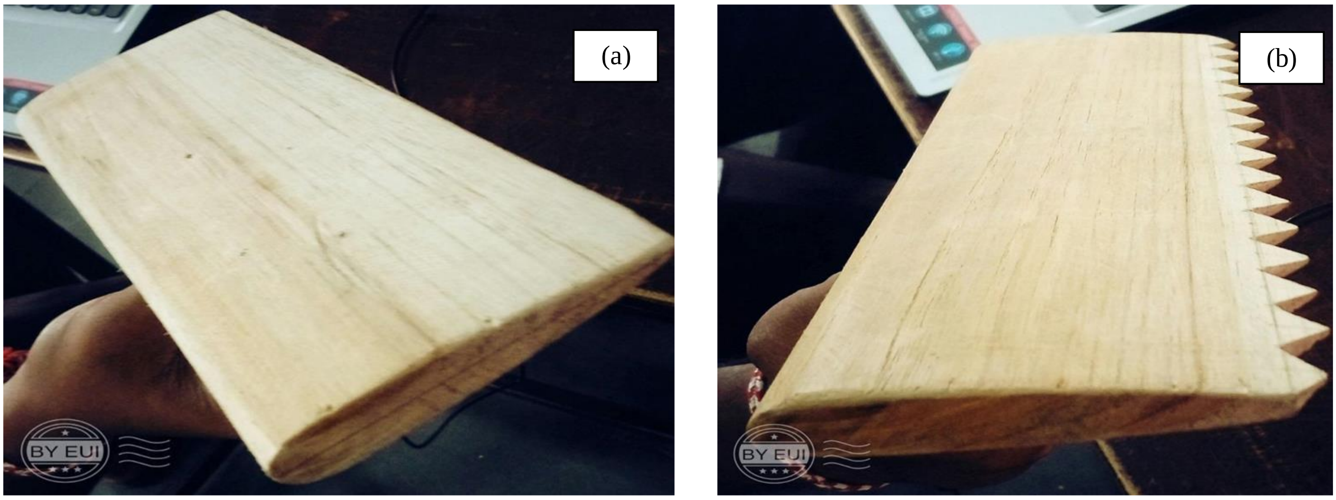


Figure 2. Experimental models (a) NACA0015 model (b) NACA0015 model with trailing edge serrations

III. METHODOLOGY

A. Pressure Coefficient (C_P)

C_P is a dimensionless number which describes the relative pressures throughout a flow field in fluid dynamics. C_P is calculated from the below expression,

$$C_P = \frac{P - P_\infty}{\frac{1}{2}\rho_\infty V_\infty^2}$$

Where:

P is the static pressure at the point at which pressure coefficient is being evaluated.
P_∞ is the static pressure in the free stream.
ρ_∞ is the freestream fluid density.
V_∞ is the freestream velocity of the fluid.

B. Force coefficients

Coefficient of lift (C_L) and Coefficient of Drag (C_D) can be calculated from the below expressions.

$$C_L = \frac{L}{\frac{1}{2}\rho_\infty V_\infty^2 S} \; ; \qquad C_D = \frac{D}{\frac{1}{2}\rho_\infty V_\infty^2 S}$$

Where

L= Lift force in N; ρ_∞= Density in kg/m^3; V_∞= free stream velocity in m/s;
D= Drag force in N; S = Span in m^2;

IV. RESULTS AND DISCUSSIONS

A. Pressure Distributions

Wind tunnel experiments were conducted on NACA4-digit airfoil. The pressure measurements were taken for two configurations of NACA 0015 airfoil with and without trailing edge serrations. The pressure distributions on upper and lower surface of airfoil are discussed. Figure 3. Shows the variation pressures for various test section velocities (*15 m/s, 20 m/s, 25 m/s and 30 m/s*) at 0^oAoA. At the leading edge, the pressure is high due to the pressure at the leading edge is higher than the atmospheric pressure. The variation of pressure reaches around 0.2 magnitude at trailing edge for both upper and lower surfaces for the velocities *15 m/s* and *25 m/s* whereas the pressure reaches around 0 at velocity *20 m/s* for both upper and lower surfaces. For 5^o angle of attack, at the leading edge, the pressure is high due to the pressure at the leading edge is higher than the atmospheric pressure. The variation of pressure reaches negative at trailing edge for both upper and lower surfaces for the velocities 15 ms/ and 30 m/s. The variation of pressures for various test section velocities (15 m/s, 20 m/s, 25 m/s and 30 m/s) at 10^oAoA, the pressure variation shows higher negative values on the upper surface at the leading edge due to the flow separation very close to the leading edge and the pressure variations at trailing edges shows almost similar as 5^0AoA for all test section velocities.

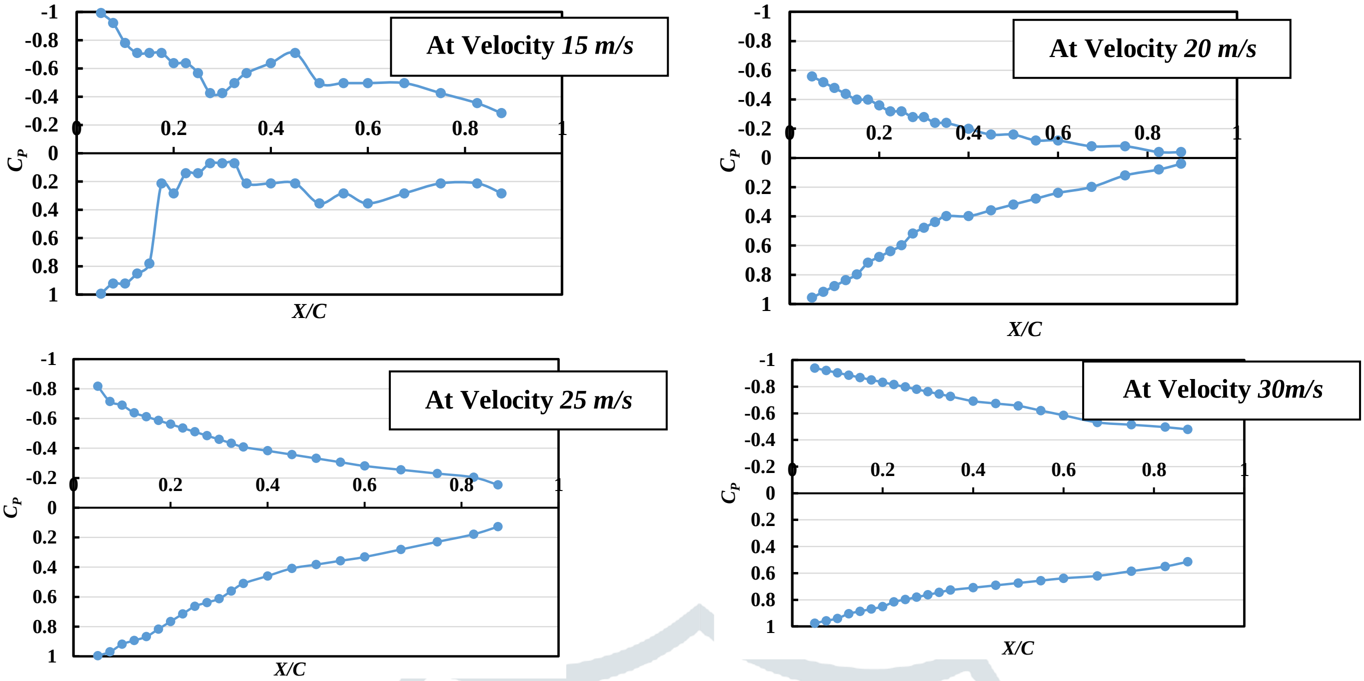
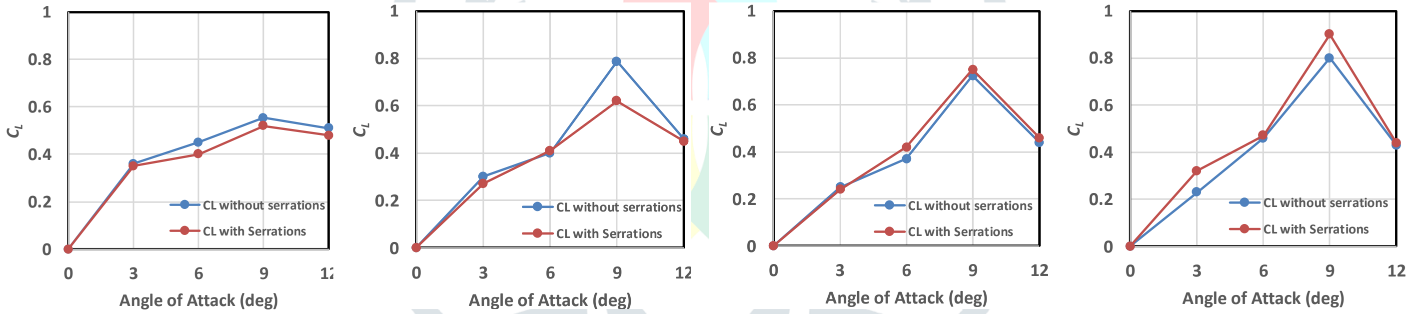


Figure 3. Variation of pressures at 0°AoA at various velocities on NACA0015 airfoil with trailing edge serrations.

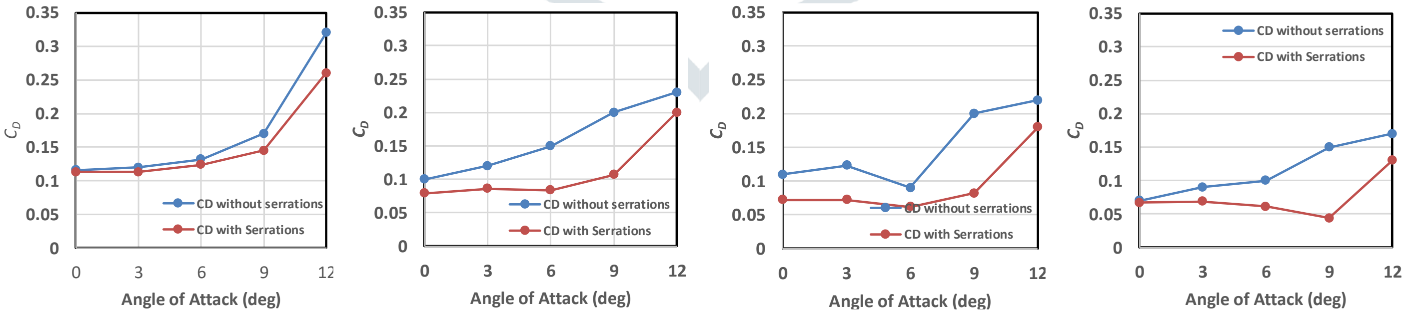
B. Aerodynamic forces

Wind tunnel experiments were also conducted on NACA 0015 airfoil. The aerodynamic force calculations have been measured using 3-component external balance on NACA 0015 with and without trailing edge serrations. The measurements have been taken for 0^o, 3^o, 6^o, 9^o and 12^o angles of attack and at various velocities of 15m/s, 20m/s, 25m/s and 30m/s. Figure 4. Shows the variations in C_L. It is observed that C_L is increased to stalling angle of attack (9^o) as expected with angle of attack and velocity from 15 m/s to 30 m/s. The effect of leading edge serrations doesn't have any effect on C_L.



(a) at 15 m/s *(b) at 20 m/s* *(c) at 25 m/s* *(d) at 30 m/s*

Figure 4. Variation of Coefficient of lift (C_L) at various angles of attack for NACA0015 with and without serrations.



(a) at 15 m/s *(b) at 20 m/s* *(c) at 25 m/s* *(d) at 30 m/s*

Figure 4. Variation of Coefficient of drag (C_D) at various angles of attack for NACA0015 with and without serrations.

Figure 5. Shows the variations in C_D. It is observed that C_D is increased with angle of attack as expected and velocity from 15 m/s to 30 m/s. The effect of leading edge serrations has little effect on C_D. For all test section velocities, the variation of C_D decreased for NACA0015 airfoil with serrations.

V. CONCLUSIONS

In this study, the effect of trailing edge serrations on the aerodynamic characteristics over the convention airfoil has been studied experimentally. The pressure distributions and aerodynamic forces are examined and analyzed. The tests were conducted at 15m/s, 20m/s, 25m/s and 30m/s test section velocities at various angles of attack of 0°, 3°, 6°, 9°, and 12°. For the present study, the following conclusions have been made.

1. Aerodynamic lift coefficient (C_L) followed the same trend till 5° angle of attack for all test section velocities for NACA 0015 with trailing edge serration model. The maximum C_L value occurred at 9°AoA is around 0.6 and around 1.0 at test section velocities of 15m/s and 30m/s.
2. For NACA 0015 with Trailing Edge Serrations, the values of C_D is decreased for all angles of attack and it is showed that lesser values when compare with NACA0015 airfoil without serrations at all test section velocities.
3. For NACA 0015 with Trailing Edge Serrations, it is found that the Trailing Edge Serration can significantly reduce the C_L, but the shape and trend of the C_L curve is similar as conventional airfoil.
4. The values of C_D for NACA0015 airfoil with serrations are 15%lesser when compare with NACA0115 airfoil without serrations for all test section velocities.

REFERENCES

[1]Xiao Liu, Mahdi Azarpeyvand "On the aerodynamic performance of serrated airfoil"-and Theunissen, University of Bristol, United Kingdom.

[2] H.A.Alawadhi, A.G.Alex and Y.H.Kim"CFD Analysis of Wing Trailing Edge Vortex Generator using Serrations"-Emirates Aviation College, Aeronautical Engineering Department, Dubai

[3] P. T. Soderman, "Aerodynamic Effects of Leading Edge Serrations on a Two-Dimensional Airfoil."NASA, 1972.

[4] S. Brennan"A wind tunnel investigation into the effect of a serrated trailing." MSc Thesis. Cranfield University, 2002.

[5] Gruber, M., Azarpeyvand, M., and Joseph, P. F., "Airfoil trailing-edge noise reduction by the introduction of sawtooth and slotted trailing-edge geometries", 20th International Congress on Acoustics, Sydney, Australia, 23 – 27, August, 2010.

[6] Stefan Oerlemans, Muuray Fisher, Thierry Maeder, Klaus Kogler., "Reduction of Wind turbine noise using optimized airfoils and trailing-edge serrations, Vol. 47, No.6, AIAA Journal, June 2009.