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Aerodynamic investigation of Extended Trailing Edge Airfoil under Various Turbulence Intensities

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SUMMARY:
Wind tunnel test were carried out to analyze the aerodynamic performance of NACA airfoil by extending the trailing edge to the maximum of 30% chord. The current work used the NACA 0020 as a base airfoil for the analysis. The angle of attack was tilted from 0° to 35° in steps of 5°, and the flow Reynolds number was fixed at 2.14×10^5. To predict the flow behavior, the surface pressure acting over the airfoil was measured at 50 pressure taps. The transient pressure was collected at a sampling frequency of 700 Hz. The trailing edge is extended to three different amplitudes of 10%, 20%, and 30% of the total airfoil chord. The dimensionless pressure and force coefficients like lift and drag are presented. The obtained results guide the revision of the trailing edge of the airfoil, which changes the flow pattern and the aerodynamic properties of the airfoil. The concept of extending the trailing edge of the airfoil without revising the main airfoil profile results in lift augmentation. Further, the extended trailing airfoil was tested at various turbulent intensities of 0.3%, 5%, and 12%. The scattering of turbulent intensity into the incoming flow adds kinetic energy to the near wall, making the flow stay attached. The lift was gradually increased until the turbulent intensity reached 5%. On exceeding the value, the fall in lift coefficient was noted. However, the airfoil follows a smooth stall in the presence of turbulent intensity. Even in high turbulence, the extended trailing edge airfoil maintains the performance of the base airfoil.
Keywords: low speed wind tunnel, extended trailing edge, turbulent intensity

1. INTRODUCTION

The airfoil geometry is generally represented by the two-dimensional shape of the aircraft wing. Wind turbine blades, propeller blades, and, most notably, aircraft wings are examples of airfoil applications. When the air medium passes over the airfoil, a frictional effect occurs between the airflow and the airfoil surface, and the region concentrated by the friction effect with the viscous flow is referred to as the boundary layer (Mohammadreza Kadivar et al., 2021). During continuous flow over the airfoil, the thickness of the boundary layer will increase. The presence of friction causes shear stress, which causes skin friction drag and causes the flow to separate from the airfoil surface, resulting in additional drag due to separation (exactly named pressure drag). The structural nature of the airfoil allows vast airflow (accelerated flow) over the upper surface. On the lower surface, however, the airflow adheres to the airfoil surface with a high magnitude of pressure. The variation of surface pressure acting on the upper and lower surfaces of the airfoil corresponding to the angle of attack remains responsible for the lift production (Tianshu Liu, 2021). When tilting the airfoil to a positive angle of attack, the adverse pressure loss takes place on the upper surface, making the flow separate from the surface. The major significance of flow separation is the stall (a sudden loss in lift and rise in drag). Aerodynamic studies are conducted to maintain higher lift by increasing the wing area. Because of the camber effect, using a Gurney flap (perpendicular to the airfoil chord) as the extended surface changes the airfoil chamber at the trailing edge and aids in producing high lift (Li et al., 2006). The supercritical airfoil with a divergent trailing edge developed by Bran E. Thompson *et al.* (2012) even performs well by improving aerodynamic properties. The symmetrical airfoil of NACA 0020 was tested experimentally by extending the trailing edge, and it was realized that this kind of modification would reduce the vortex strength. The extended plate at the trailing edge avoids the sudden interaction of upper and lower side flow there by increasing the vortex core length. The aerodynamic behavior of an extended trailing edge airfoil in the presence of various turbulence intensities has also been studied in the current work (Connor, 2018; Swalwell, 2004; Arunvinthan et al., 2020; Leon and Hearst, 2021).

2. DETAILS OF THE EQUIPMENT AND TECHNIQUES APPLIED IN THE EXPERIMENT

The experiment was carried out in a low-speed wind tunnel facility available at the Aerodynamics Laboratory, SASTRA Deemed University. The wind tunnel's turbulence intensity is 0.3% before the turbulence grid is fixed. Fig. 1 provides an idea of the complete view of the test setup. The NACA 0020 airfoil with a 10 cm chord has been selected for the research work. A thin stainless steel plate of 2 mm thickness is shaped as an extension with varying amplitude. A 64-channel pressure scanner is used as a pressure measuring device.

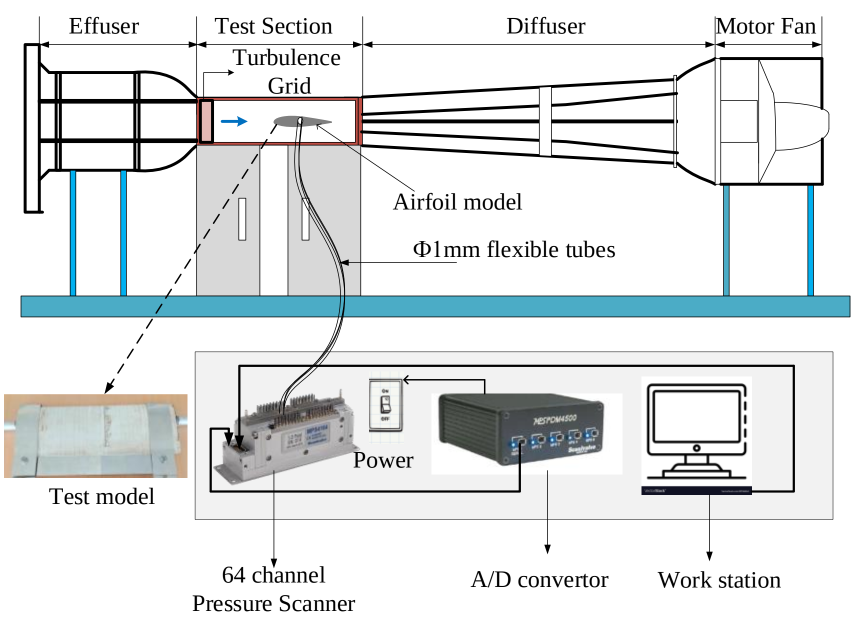

Figure 1. Schematic representation of integrated experimental setup

3. RESULT AND DISCUSSION

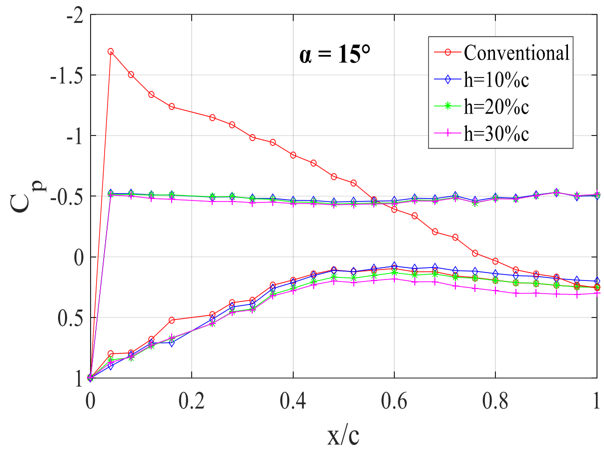

Figure 2. Variation of non-dimensional pressure Vs airfoil chord with respect to extension amplitude at T.I = 0.3%.

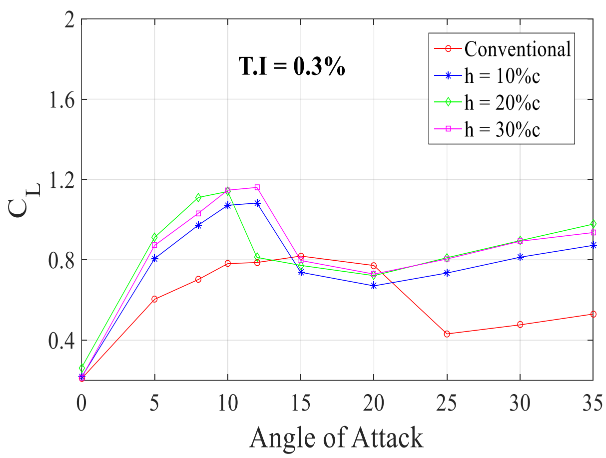

Figure 3. C_L Vs α with respect to extension.

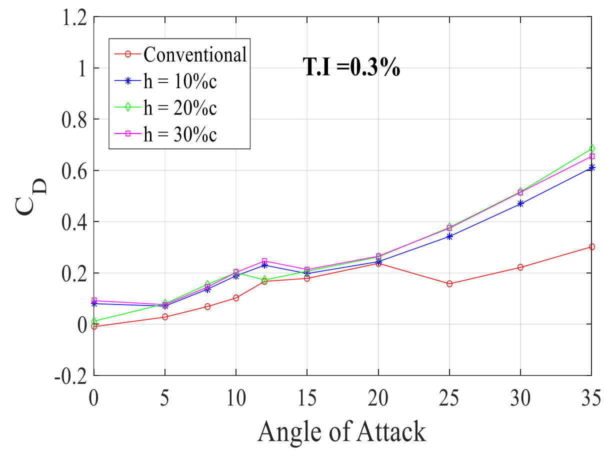

Figure 4. C_D Vs α with respect to extension

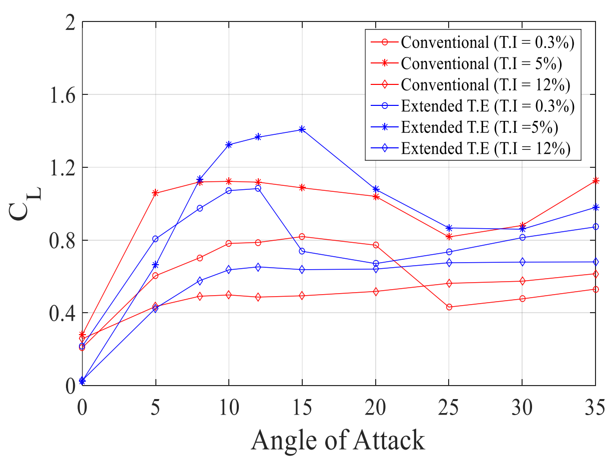

Figure 5. Comparison of lift for various T.I

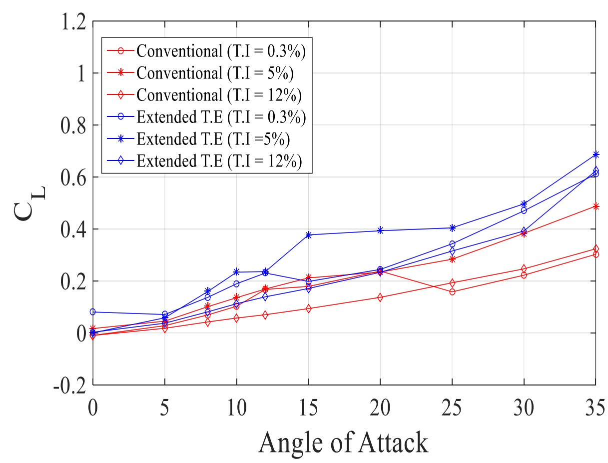

Figure 6. Comparison of drag for various T.I

From Fig. 2, the pressure behaviour at the pressure side remains similar for both conventional and extended trailing edges, denoting the unchanged behaviour for both conventional and modified cases. On the suction side, the C_p value changes for all extended trailing edge cases compared to the base airfoil. Unlike the conventional model, the peak negative pressure is limited to -0.5 and plateaus through a chord, indicating the presence of prestall. The traditional model measures -1.75, followed by a sudden recovery, indicating stalling. The above statement was provided from Fig. 3. The lift increased because of the pressure difference, and the drag penalty was less, as shown in Fig. 4. On testing the conventional and extended trailing edges with T.I. of 0.3%, 5%, and 12%. The conventional airfoil loses performance at a higher T.I. of 12%, but at a moderate T.I. of 5%, it shows good lift increment. However, the extended trailing edge airfoil outperforms the conventional airfoil in any range of turbulent intensity, as shown in Fig. 5. The trend of the drag plot shows no significant rise in the drag component compared to the conventional case even when testing in the presence of turbulence intensity (Fig. 6).

7. CONCLUSIONS

For the extended trailing edge airfoil of amplitude (h = 30% c) than the base airfoil, lift increases linearly (C_l) by approximately 26% maximum. However, the stall occurred about 3° above the base airfoil. In the conventional case, extending the airfoil tailing edge prevented a deep pressure loss followed by a sudden recovery. The extended surface avoids the sudden contact of suction side flow and pressure side flow of the airfoil at the trailing edge. As a result, increasing the vortex core length reduces pressure drag. The performance of the base airfoil is reduced in the presence of high turbulence intensity; however, the extended trailing edge combined with the base airfoil maintains the performance of the base airfoil even in the presence of high turbulence intensity.

ACKNOWLEDGEMENTS

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