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Comparison of Aerodynamic Performances of Fowler and Gurney Flaps by Numerical Simulation

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Abstract—*Flaps are types of high lift devices used for altering the lift generation in aircraft control surfaces and other lift generating devices which are made of aerofoil cross-sections. Especially at times oftake-offs and landings, flaps are of prime importance for controlling the aircraft. In the present study, a turbulent, two-dimensional steady flow past a NACA0026 aerofoil with two different flaps, namely Gurney and Fowler flaphave been investigated in view of comparing their performances. Numerical simulations have been carried out using commercial CFD package ANSYS 14.5 with an unstructured grid finite volume method. In a constant free stream velocity, the velocity and pressure contours along with the velocity streamlines have been obtained and compared for both the flaps. Both, the lift and drag coefficients as well as the corresponding lift to drag ratio have been found to be higher in case of Fowler flap, ascertaining higher performance index for the same.*

1. INTRODUCTION

Flaps have been an essential object in aerodynamics of flight dynamics since ages [1], especially in the aspects of maneuvering and control of flying aircraft [2]. Flaps have been attached to aerofoil sections in order to change the angle of attack of the same thereby providing alteration in lift generation [3]. In case of an aircraft, different types of flaps are used at trailing edges of the wings as well as the vertical and horizontal stabilizers. Flaps have also been effectively used for other high-lift devices [4] with aerofoil sections. However, the main object of using flaps are to enhance the performance of aircrafts by controlling the angles of attack and thus the lift generated in its various parts having aerofoil sections. Different types of flaps namely plain flap, split flap, slotted flap, Fowler flap, Gouge flap, Fairey-Youngman flap, Zap flap, Krueger flap, Gurney flap and many more [5,6,7,8,9,10] have been used in real-life aircrafts. However, Fowler and Gurney flaps have been the most widely used varieties of all these [11]. In view of availability of so many types of flaps, it is of utmost necessity to have a comparative study between performances of various flaps when used at the trailing edge of the same aerofoil section. The present simulation study focuses on determination and comparison of pressure contours and velocity profile generated in cases of Fowler and Gouge when used at the end ofa NACA0026 aerofoil placed in a closed-circuit wind-tunnel.

2. METHODOLOGY:

A rectangular flow domain (5m x 2.5m) has been considered and an aerofoil with Fowler and Gurney flaps have been studied with a NACA 0026aerofoil being set at zero angle of attack. The length of the Fowler flap is 9cm and the flap is opened at an angle of 23˚. The length of the Gurney flap is 2% of the chord length.

The governing equations used in this present studyhave been taken to be same as those of the numerical simulations performed by Bagchi et al. [12] for flow over an aerofoil, with the lift and drag co-efficients being defined in the same way. To perform the required numerical simulations, a finite volume based CFD code ANSYS Fluent 14.5 has been used. A steady analysis has been performed and a pressure-based solver is chosen as the numerical scheme. All the numerical conditions and constraints have been kept identical for both the flaps. A viscous and turbulent standard k-ε 2-equation model has been used with standard wall functions and curvature corrections. The model constants have been taken as,C_{mu}= 0.09; C_2-ε= 1.92; C_1- ε= 1.44; *TKEPrandtl No.* = 1 and *TDR Prandtl No.* = 1.3. For better and faster convergence results at steady turbulent models,the solution method is based on the SIMPLE scheme.The inlet conditions of the model have been set to velocity-inlet with a free stream velocity of 20m/s. The turbulent intensity has been limited to 5% and the turbulent viscosity ratio set to 10. The upper and lower boundaries of flow domainhave been set to specified shear of zero magnitude withthe outlet conditions of the model set to outflow. A least squares cell based gradient has been used and the momentum, Turbulent Kinetic energy and Turbulence Dissipation rate has been solved using the second order upwind scheme for more accurate results. The Lift and Drag coefficients have been monitored on the aerofoil. The Standard initialization has been done from inlet and the solution has seen to be converged within 800 iterations with the total calculation duration of 15 minutes.

The ANSYS Meshing package has been used to create an all Triangles based unstructured grid with the maximum size and face size of element limited to 0.1m. The defeaturing tolerance has been reduced to 1.e-006m. The total numbers of nodes and elements have been37722 and 70207 respectively for the Gurney Flap, while the Fowler Flap has been associated to 49568 nodes and 92170 elements. The Mesh details have been shown in Fig. 1.

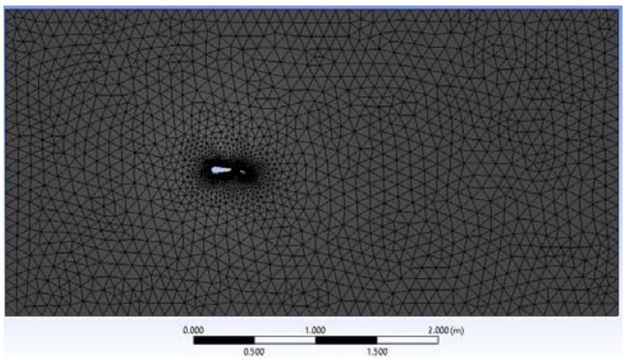

Fig. 1: Mesh details of Fowler flap

3. RESULTS AND DISCUSSION

The pressure and velocity contours as well as the streamlines for flow past the flapped aerofoil have been shown in Figures 2-7. The contours delineate the pressure and velocity profiles of flow past the two flaps. The red color represents the maximum value while the minimum value is denoted by blue.

At steady state, the lift and drag coefficients of the Gurney flap have been observed to be 22.64 and 4.05 respectively. The same coefficients for the Fowler flap have been 165.04 and 8.88 respectively. The lift-to-drag ratio, which is an indicator of the performance of the aerofoil, has been observed to be 18.59 for the Fowler flap while 5.60 for the Gurney flap.

The pressure contour for Fowler flap in Fig. 2 clearly shows very low pressure at the upper side and high pressure at the lower side, thereby indicating possibility of high lift force generation, while that for the Gurney flap in Fig. 3 shows less variation of pressure between the two surfaces. So, the pressure contours also suggest a higher lift generation capability for the Fowler flap thereby enhancing its performance. The same conclusion can be drawn from the drag-to-lift values of both the flaps as mentioned earlier.

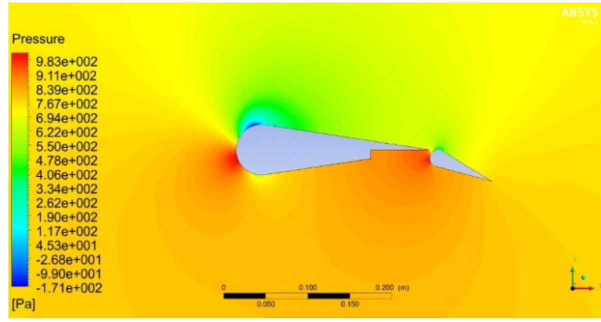

Fig. 2: Pressure contours of Fowler flap

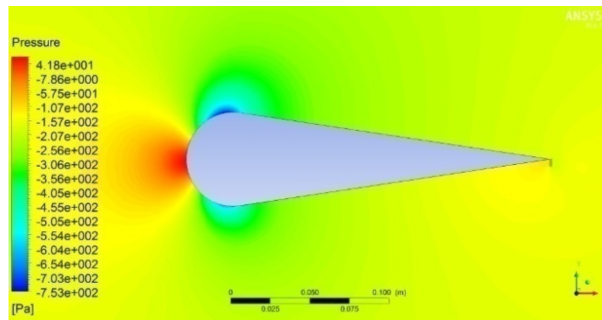

Fig. 3: Pressure contours of Gurney flap

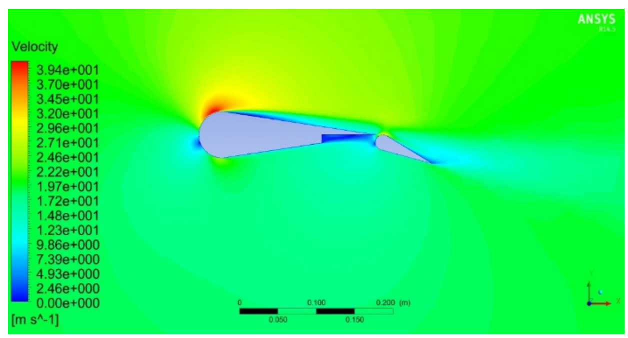

Fig. 4: Velocity contours of Fowler flap

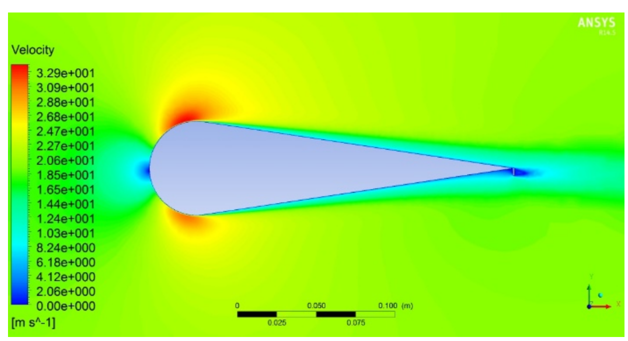

Fig. 5: Velocity contours of Gurney flap

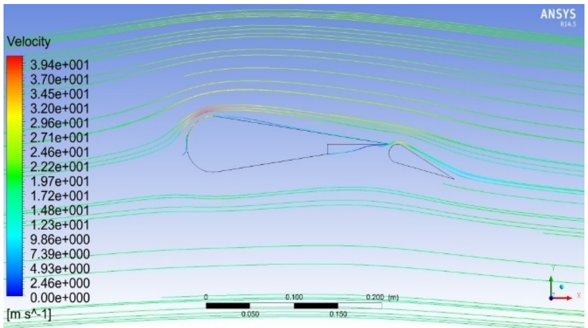

Fig. 6: Velocity streamlines of Fowler flap

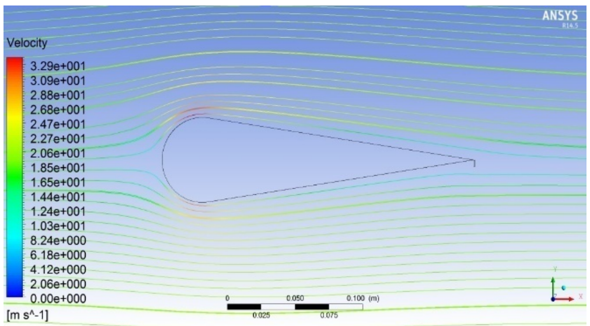

Fig. 7: Velocity streamlines of Gurney flap

4. CONCLUSION

The lift coefficient for the Fowler flap is observed to be more than 7 times of that of the Gurney flap. Simultaneously, the drag coefficient of the Fowler flap is observed to be double of that of the Gurney flap. So it can bereadily concluded that aerodynamic performance of the Fowler flap is better than the Gurney flap, as is evident by the much higher lift-to-drag ratio of the former.

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