Experimental and Theoretical Investigation for the Improvement of the Aerodynamic Characteristic of NACA 0012 airfoil

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***Abstract*—** In the present study , an experimental and theoretical investigation has carried out to study the enhancement of lift on NACA 0012 airfoil as well as lift to drag ratio by adding some of high lift devices. . It includes the enhancement of the lift of the airfoil by using three types of high lift devices. The experiment was executed by using a wind tunnel with Reynolds number equals to 2.7×105 based on the chord line length of the airfoil. In the experimental work the test was carried out for the base line airfoil only for angles of attack 0°,4°,8°,12°, 16° The theoretical study was executed using CFD package which is ANSYS FLOTRAN 12.1 by using CAD preparation of two dimensional NACA 0012 airfoil. The study investigates adding a Gurney flap with two different heights 2% c and 3% c, extended flaps with two different lengths and deflection angles, using 2% c extended flap with deflection angles equals 0° and 5°, 4% c extended flap with deflections angles equals 5°. A 3% c T flap was also added. To show the effect of the cavity in front of gurney flap, a 3% c closed flap or filled in flap was added to the airfoil and compared with the same height of Gurney flap. a good improvement in lift coefficient for gurney flap and extended flaps was obtained . The best results that could be achieved using Gurney flap was found to be with height = 2% .The best results that could be achieved using static extended trailing edge was found with height 4% C and deflection angle =5°because it has larger lift to drag ratio. Lift coefficient of closed flap was half of that obtained by Gurney flap.

***Keywords*—** Aerodynamic Characteristic of NACA 0012 airfoil

I. Introduction

IN recent years there has been an increased interest in primary criteria in the design of wings include maximizing efficiency and control; that is, increasing desired effects (e.g. lift) while diminishing undesired effects (e.g. drag) so that the airfoil becomes more functional and provides sufficient means of control. High-lift aerodynamics continues playing an important role in the design of a new aircraft. Improved high lift performance can lead to increase range and payload, or decrease landing speed and field length requirements. Hence, there is a continuous need for improving the maximum lift and lift-to-drag ratio, L/D.

The Gurney Flap is named after American aero dynamist Dan Gurney who introduced in the form of a vertical tab attached to the trailing edge of an ordinary aerofoil. Usually, his use on the racing car wing is intended to keep a racing car on the road it improving wing efficiency. It is a simple length of aluminum or carbon fiber right-angle rigidly bolted, riveted on the pressure side perpendicular to the chord as shown Fig (1)

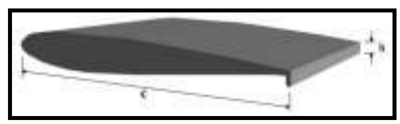

Fig. 1 Isometric airfoil with gurney flap

Extended flaps is thin splitting plate mounted at the trailing edge of an airfoil, but rather than protruding 90° to the chord line, it is mounted with a small deflection angle (5°-10°) figure (2).

Fig. 2 Extended flap

A two Gurney flaps attached to both the upper and lower surfaces of the airfoil making the modification as same as T letter, therefore it is called T flab.

The study on Gurney flap was first reported by **Liebeck. ,(1978), [1]** who conducted the experiment for a Newman □symmetric aerofoil with a 1.25% c Gurney flap in a wind tunnel. In comparison with the aerofoil without the Gurney flap, Gurney flap increased the lift coefficient and maximum lift coefficient greatly; meanwhile, the meanwhile, the zero lift angle-of-attack and drag of the aerofoil were reduced. Liebeck also proposed the existence of a separation bubble upstream of the Gurney flap, and the presence of two counter- rotating vortices just downstream of the Gurney flap.

Wadcock, (1987), [2], performed wind tunnel tests at a Reynolds Number of 1.64 × 10^6 on a baseline NACA 4412 airfoil. These tests showed a significant increase in the lift coefficient, shifting the lift curve up by 0.3 for a Gurney flap of 1.25% of the chord length, and providing a greater maximum lift. There was no appreciable increase in drag until

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the Gurney flap was extended beyond about 2% of the airfoil chord length, at which point the flap extended beyond the boundary layer thickness.

Giguere, P. et al, (1995),[3]. Quantified the effects of Gurney flaps with respect to their height scaled to the thickness of the boundary layer. Using this scaling, it is observed that Gurney flaps are effective when the heights are at the same scale as the boundary layer; when the boundary layer is significantly thicker, there is essentially no effect.

Wang et al (2006), [4] studied the Gurney flap on a swept wing model at Mach numbers ranging from 0.05 to 0.7 through force measurements. The largest increments of the maximum lift coefficient and maximum lift- to-drag ratio were 16.8 and 24.1%, respectively

The experimental and computational study performed by **Ross et al, (1995), [5],** to determine the effect of Gurney flaps on two-element NACA 632-215 Mod B airfoil. **Jang et. al.(1992), [6]** used an incompressible Navier-Stokes code to compute flow field about NACA 4412 airfoil with Gurney flap heights ranging from 0.5% to 3% of chord.

II. Experimental Setup

The experiment was conducted in the low speed wind tunnel an open circuit type figure (3). The testes were performed at a free stream velocity of 29m/s Providing Reynolds number, Re $=2.7\times 10^5$ based on the airfoil chord.

Fig. 3 airfoil inside the wind tunnel

The airfoil shape chosen for this work was the NACA0012, airfoil which has zero camber, and its maximum thickness is 12% of the chord at the quarter-chord location. NACA0012 airfoil used in this experiment had a chord length of 0.152 m, and span (b) of 460 mm.

III. Theoretical Study

The CFD analysis in the present study can be used to simulate the flow around a NACA 0012 airfoil model and explain the effects of the different types of flaps on the enhancement of the lift on airfoil. In the present study the CFD program was ANSYS12.1 by using FLOTR CFD simulation with Reynolds No. equals to $2.7*10^5$ based on the chord line of the airfoil. c is the chord length, x is the position along the chord from 0 to c, and τ is the maximum thickness as a fraction of the chord. Mapped mesh was used figure (4).

Fig. 4 mesh generation

The boundary domain is enclosed by the wind tunnel walls of the closed test section some reasonable.

IV. Result And Discussion

The lift and drag coefficients of the airfoil at different angle of attack. Figure (5) shows the lift and drag coefficient for the airfoil with different sizes of ***Gurney flap.*** Gurney flap substantially increase the maximum lift coefficient by 32.89% and 39.42% for 2%c and 3%c Gurney flap respectively Consequently, the stall angle slightly degreased from 12° to 10° for both sizes of Gurney. Figure (6) shows the lift coefficient as a function of angle of attack for the model with extended flap, According to this figure, the C_L distribution is shifted up and the lift is enhanced depending on the deflection angle and relative length of extended flap. . Figure (7) show the effect of closed flap on the lift coefficient. This figure shows an increase in lift coefficient of approximately 16.5%, which is slightly less than the 2% flap case. This result seems reasonable since the rear point of the camber line is effectively the same for these two cases, though the camber lines themselves are not the same.. The effect of ***T strip*** on the baseline wing lift curve is shown below in Figure (8). T-strips produced an increase in maximum lift coefficient. However, T-strips produced no shift in the wing zero-lift angle of attack because the flow field is symmetric, in another word, the upper half of the T effectively canceling the effect of the lower half.
Figure (17) show the stream line of the airfoil with 3% c Gurney flap and figure (18) show the velocity vector of the same Gurney flap. At zero angle of attack, two counter-rotating vortices of similar strength are visible aft of the Gurney flap. As angles of attack increase, a recirculation region and retarded flow can be seen on the airfoil lower surface, at the front face of the Gurney flap and the vortex near the airfoil upper (suction) surface becomes dominate. This flow field agrees with that hypothesized by **Liebeck [1]**

V. Conclusion

The presence of a Gurney flap on an airfoil served to increase the lift generated on the body. As the height of the Gurney flap was increased, the lift also increased with small drag penalty. The zero lift angles degrease. The best results that could be achieved using Gurney flap was found to be with height = 2% c because it gave lift to drag ratio higher than Gurney flap 3% c. In general, Gurney flaps are not suitable for cruise flight due to the reduced lift to drag ratio by the larger drag penalty at lower lift coefficients. Adding 3% T _Gurney flap reduces the lift and increase drag with compared with airfoil with 3% c Gurney flap. Therefore the lift to drag ratio was less than 3% c Gurney flap. Airfoil with closed flap generated approximately half the lift increment of the open-cavity case. Thus, it appears that a significant part of the lift increment produced by the Gurney flap results directly from the upstream shedding and its influence on the trailing wake. The best results that could be achieved using static extended trailing edge was found with height 4% c and deflection angle =5°because it has larger lift to drag ratio. Static extended trailing edge flap can be used in cruise flight because it has a good potential to improve the cruise flight efficiency.

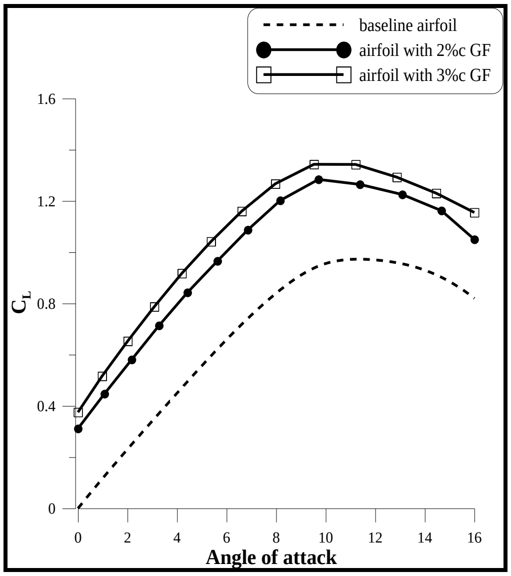

Fig. 5 Lift coefficient versus AOA for various heights of Gurney flap

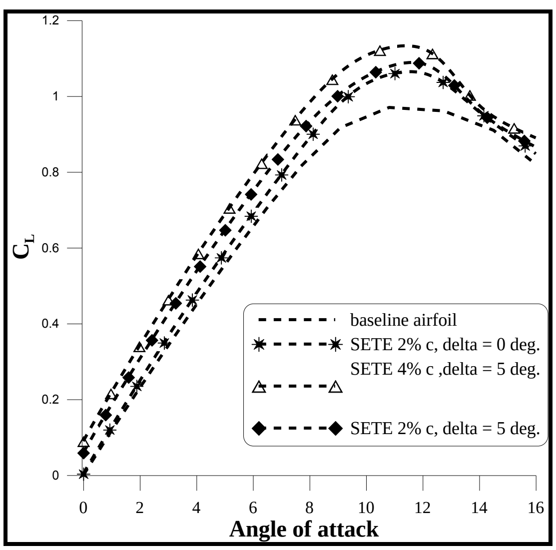

Fig. 6 Lift coefficient versus AOA for various heights and deflection angles of ext. flap

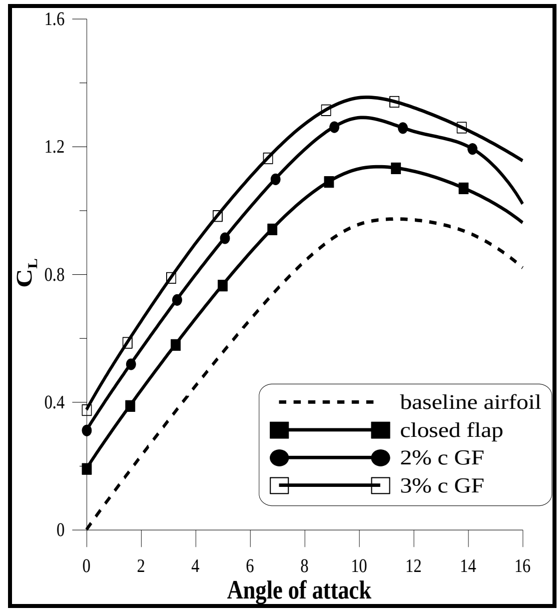

Fig. 7 Lift coefficient versus AOA for Gurney flap included closed flap

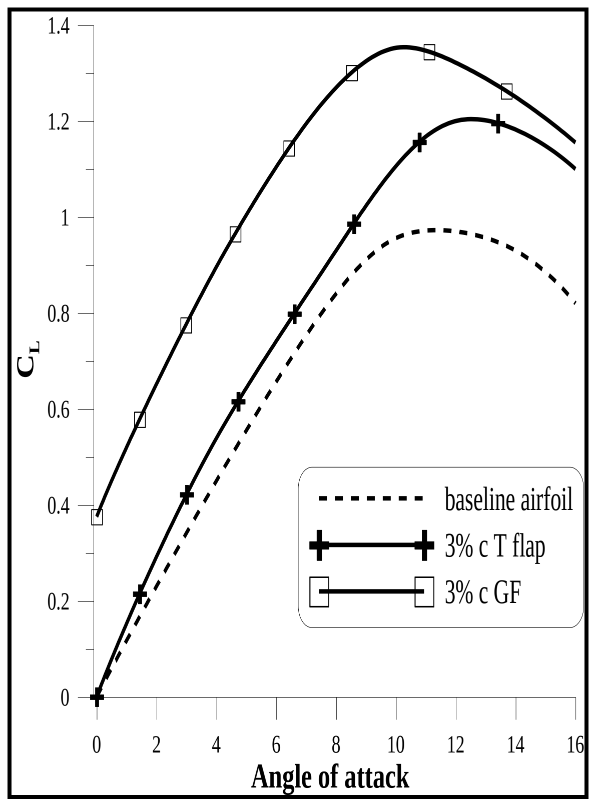

Fig. 8 Lift coefficient versus AOA for T Gurney flap

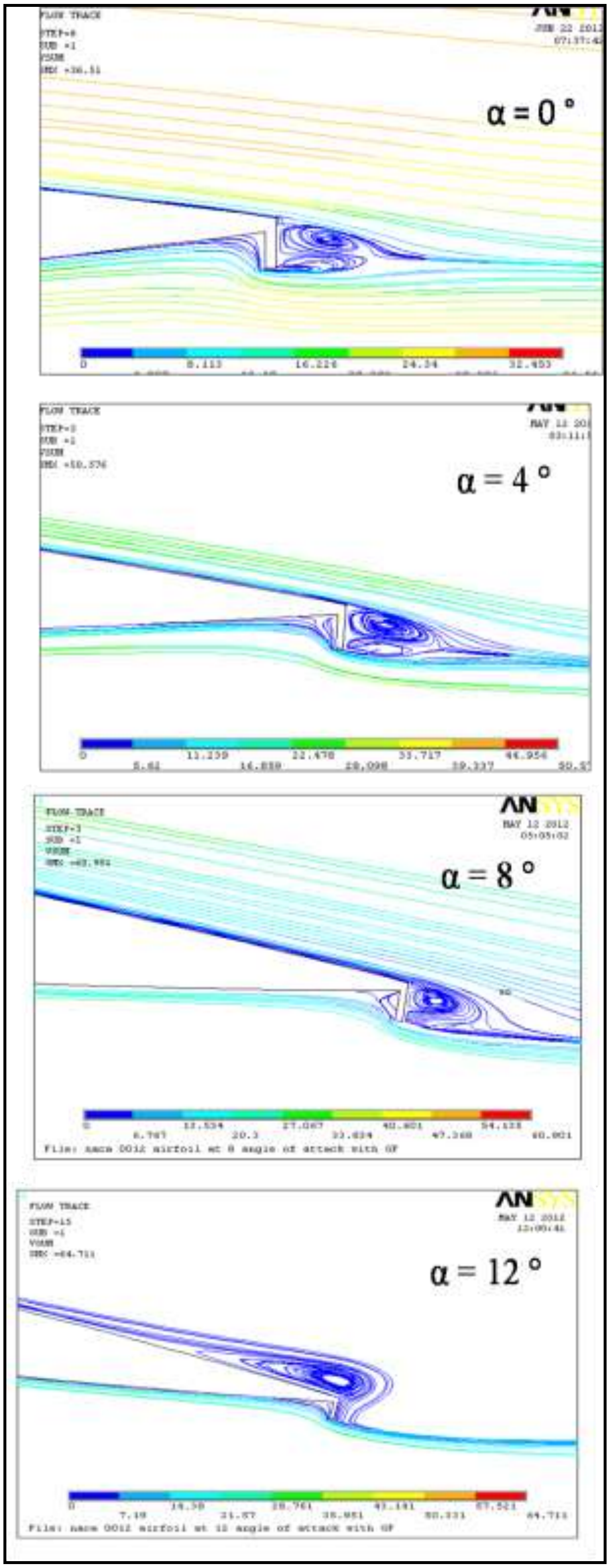

Fig. 9 Stream lines of NACA 0012 Airfoil with 3% c Gurney flap

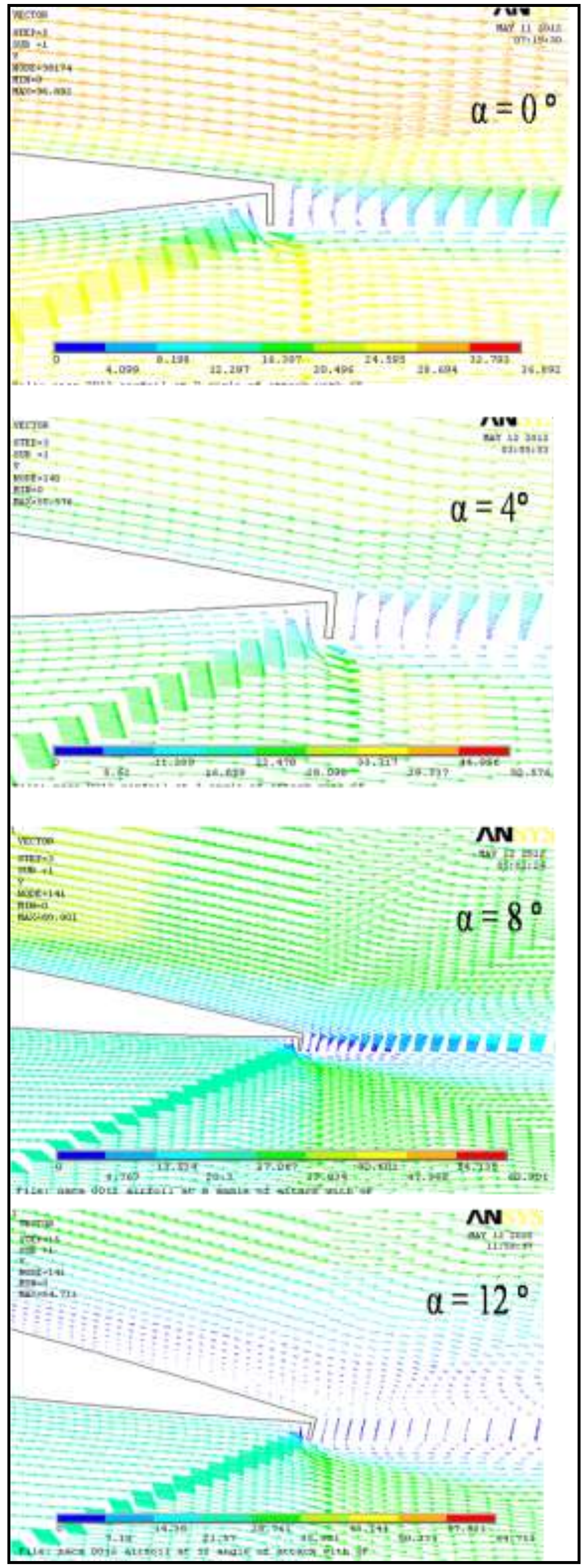

Fig. 10 Velocity Vector of NACA 0012 Airfoil with 3% c Gurney flap

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