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EXPERIMENTAL STUDY TO THE EFFECT OF GURNEY FLAP ON THE CLARK Y-14 AIRFOIL WING MODEL

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ABSTRACT: An experimental wind tunnel investigation was undertaken to determine the effect of Gurney flap on the aerodynamic characteristics of Clark y-14 airfoil wing at a Reynolds number of 2.1×10^5. The heights of plain flap change from (1.19% C) to (5.60% C).In addition the (5.60% C) was serrated to different heights and configurations. The Gurney flap improve performance of Clark y-14 airfoil wing compare with clean wing, the results show that the most beneficial Gurney flap is (1.19% C) which increase maximum lift to drag ratio to (5.31%) compared with clean wing. The serrated Gurney flap tend to be increase lift to drag ratio significantly, the rectangular serrated Gurney flap provides the best performance among the serrated Gurney flaps by improve lift to drag ratio to (42.8%).

KEYWORDS: Rectangular wing, Gurney flap, lift enhancement, wind tunnel tests, lift to drag ratio.

1 INTRODUCTION

Lift increase is necessary in order to climb to the cruise altitude at take-off and to be able to fly at the necessary low maneuver speeds in case of landing .While a rise in lift for the wings is easily obtained by increasing the angle of attack, the necessary lift improvement to obtain maximum performance of the aircraft is unrealizable without the use of high lift systems [1]. The Gurney flap is a vertical tab added to the trailing edge on the pressure side of a wing. Car racer "Dan Gurney" is credited as the inventor in the early 1970s [2], this flap was never tested until Gurney's aerodynamicist introduced it to Robert Liebeck [3], who tested it in the wind-tunnel.

The direct effect of Gurney flap on lift and drag were demonstrated by other experimental studies and it was found that the improvement in aerodynamic performance diminishes rapidly by increased flap height [4]. Gurney flaps work by separating flow near the trailing edge, inducing vortices that work to turn the flow. In doing so, pressure is decreased on the suction side and increased on the pressure side. This results in an increase in C_{Lmax} of the airfoil and a shift in the zero lift angle of attack [5]. , pressure and velocity measurement on airfoil surface as well as PIV (particle image velocimetry) measurement and die-injection flow visualization has been carried out by various researchers. Instantaneous flow patterns around the G.F. show a wake containing an alternatively shed Karman vortex sheet. The time averaged velocity profile concluded that the wake downstream the flap consisting of a rotating vortices is turned downwards Fig. 1 [6].

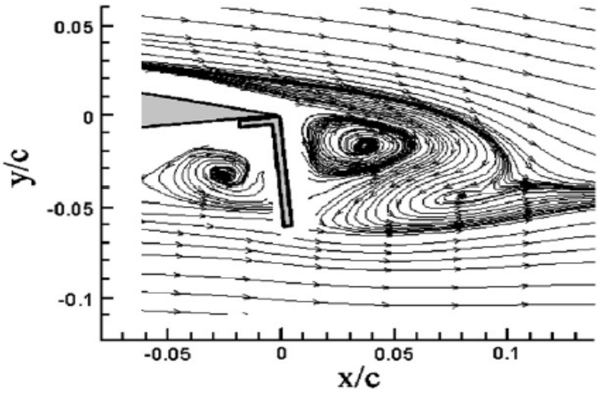

Fig. 1. Time-averaged streamlines with 6% C G.F. at α=2.5° [6].

The effect on drag that a Gurney flap exerts is largely dependent on the size of the flap. A Gurney flap of 5% can actually increase the lift to drag ratio, while increasing the size has a progressively higher drag penalty. [7]. D. R. Troolin et al [8] study a NACA 0015 airfoil with and without Gurney flap through time-resolved PIV Two distinct vortex shedding modes were found to exist and interact in the wake downstream of flapped airfoils. The dominant mode resembles a Kàrmàn vortex street shedding behind an asymmetric bluff body. The second mode, which was caused by the intermittent shedding of fluid recirculating in the cavity upstream of the flap.

Michael A. Cavanaugh et al. [9] conducted a Wind Tunnel Test of Gurney Flaps and T-Strips on an NACA 23012 Wing Results showed that Gurney flaps produced an increment in lift coefficient, a negative shift in the zero-lift angle of attack, T strips produced an increase in the slope of the lift curve and an increase in maximum lift coefficient, Gurney flaps produced a negative (nose-down) shift in the pitching moment. Lee T. Su [10] investigated the impact of Gurney flaps of different heights on the flap surface on the aerodynamic and wake characteristics of a NACA 0015 airfoil. The results shows that the addition of the Gurney flap to the produced a further increase in the downward turning of the mean flow (increased aft camber), leading to a significant increase in the lift, drag, and pitching moment.

The present work aimed to conduct an experimental study of full scale cambered rectangular wing Clark y-14 is to evaluate the aerodynamics characteristics of clean and flapped airfoil for different Gurney flap height ranged from (1.19% C to 5.65% C) and different serration depth on (5.6% C) mounted on the pressure side of the airfoil at different AOA ranged from (-8° to 18°).

2 MATERIALS AND METHODS

The experimental works were performed at The AEROLAB Educational Wind Tunnel (EWT) at power laboratory of Alnahrain University. The Tunnel is of Open Circuit test section, maximum speed is in excess of (64.8 m/s). Its contraction ratio of 8.3:1 and low turbulence level of 0.12% (average turbulence based on measurements taken at 13 different speeds) [11]. The tests were conducted at speed equal to 35.7 m/s Corresponding to Reynolds numbers of $0.21x10^6$, the clean and flapped wing model were tested at different angels of attack (α) ranged from (-8°) to (18°).

The wing model used was a rectangular wing of a Clark y-14 airfoil Fig. 2, the wing section manufactured from steel and had a maximum thickness of 14 % chord. And an aspect ratio (AR) of 2.77, the wing model used has 25cm span and 9cm chord. Model is mounted in the EWT by fastening it to the sting force Balance. The model positioning system (MPS) is a series of parallel arms mounted to a gearbox. The sting balance mounts to the top of the MPS vertical arms and provides a perfect perch for models. The model positioning systems allows for pitch angle adjustment from approximately +20° to -20°.

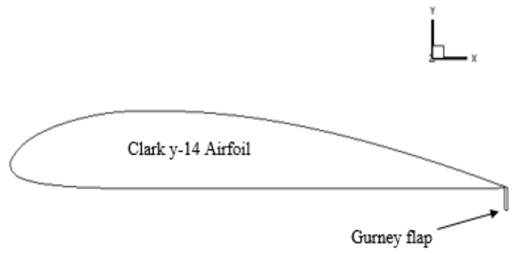

Fig. 2. Airfoil profile

The EWT system is provided with electronic instrumentation which consists of three-component sting Force balance. In order to take measurements, these instruments require the provided data acquisition (DAC) system of LABVIEW software**.** The Gurney flap for different heights and different configurations Fig. 3. was manufactured based on the airfoil cord length with constant thickness of 1.19% of cord length which equal to (1mm) the plain Gurney flap have different heights of (1.1.9, 2.3, 3.34, 4.44 and 5.6 percent of cord length) which equal to (1mm, 2mm, 3mm, 4mm, 5mm) respectively **.** The serrated Gurney flap was also based on airfoil cord length, the 5.6% C (5mm) Gurney flap was serrated, the serration came into three shapes**,** the triangular shape which has two heights (2.87, 3.9 %C) which equal to 2.5 mm and 3.5 mm respectively, rectangular shape of 3.9 % C (3.5 mm) and Semicircular shape which has radius of 1.95 %C (1.75 mm). Fig. 4. Shows the wing with Gurney flap inside test section.

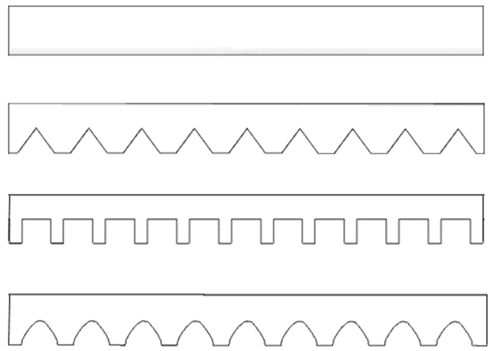

Fig. 3. different Gurney flap configurations

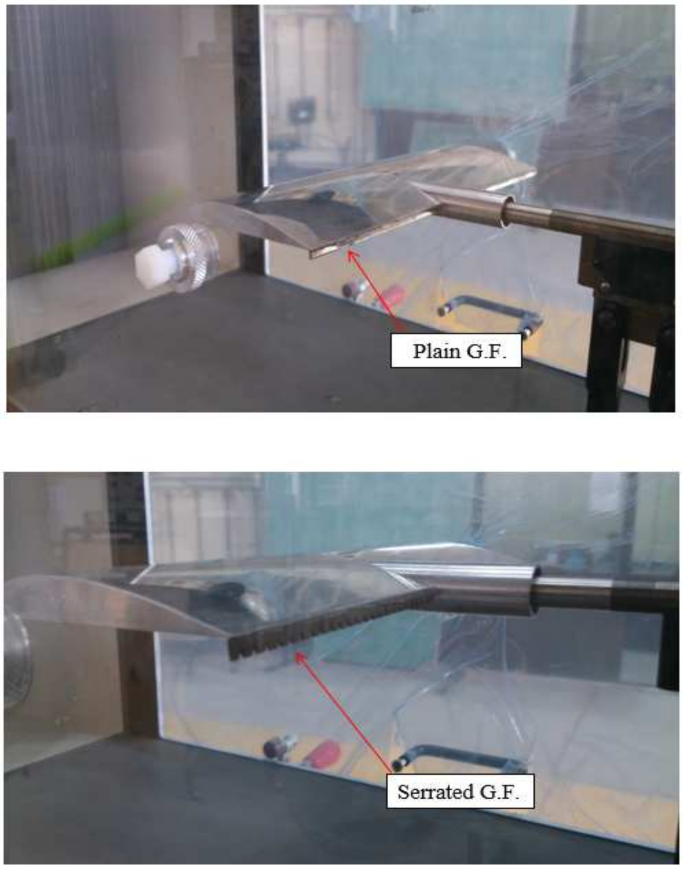

Fig. 4. Gurney flaps

3 RESULTS AND DISCUTION

Plain Gurney flap increase the lift coefficient of Clark y-14 airfoil wing section compared with clean wing as in Fig. 5 Which shows lift coefficient against angle of attack, these results indicate that Gurney flap increase the effective camber of the wing. Table 1. shows the percent increase of maximum lift coefficient, stalling angle for all plain Gurney flap heights. The increase in lift obtained with Gurney flap comes at the price of increased drag as shown in Fig. 6, where the Gurney flaps produce more drag than the clean wing, the drag is greater with the larger-size Gurney flap, table 2 show the percent of experimental drag increase at all heights of Gurney flap. Figure 7 show the drag polar for all cases of plain Gurney flap heights it is clearly that Gurney flap shift the polar to the right for low and moderate lift coefficient except the 1mm G.F. where it shift the polar to the right because of it is have lower drag coefficient than other G.F. heights. Figure 8 show the lift coefficient to drag coefficient ratio versus angle of attack, it is show that 1mm G.F. has better efficiency than clean wing and other heights of Gurney flaps, the increase in the maximum lift coefficient to drag coefficient ratio by (5.31%) at angle of attack (α=1) compared with clean wing.

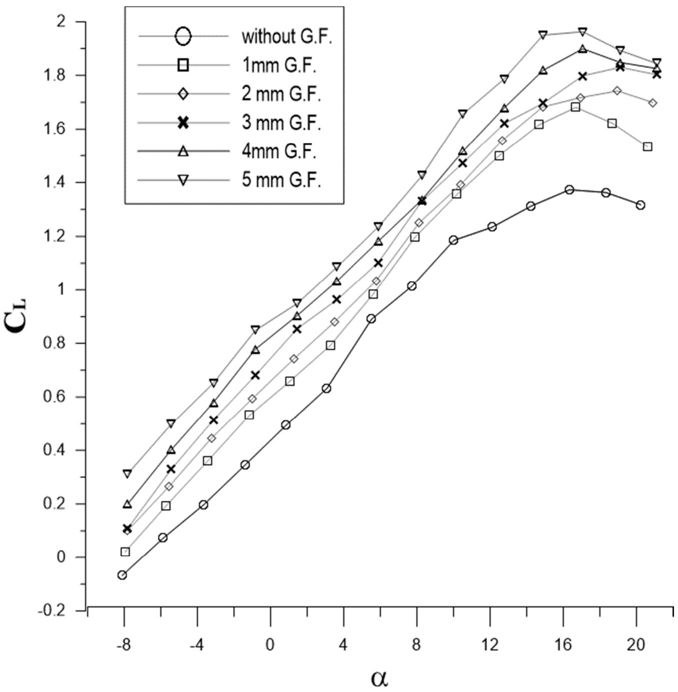

Fig. 5. Lift coefficient (C_L) versus angle of attack (α) for plain G.F.

Table 1. Percent increase in the experimental maximum lift coefficient and the stall angle and zero lift angle of attack.

G.F. heights	without	1mmG.F.	2mm G.F.	3mm G.F.	4mm G.F.	5mm G.F.
% Increase of maximum lift coefficient	-	22.62	24.81	30.65	37.95	43.06
Stall angle	16	17	18	19	17	17

Table (2): percent increase in the maximum drag coefficient

G.F. heights	1mm G.F.	2mm G.F.	3mm G.F.	4mm G.F.	5mm G.F.
% Increase of maximum drag coefficient	15.3	57.9	73.5	84.6	88.46

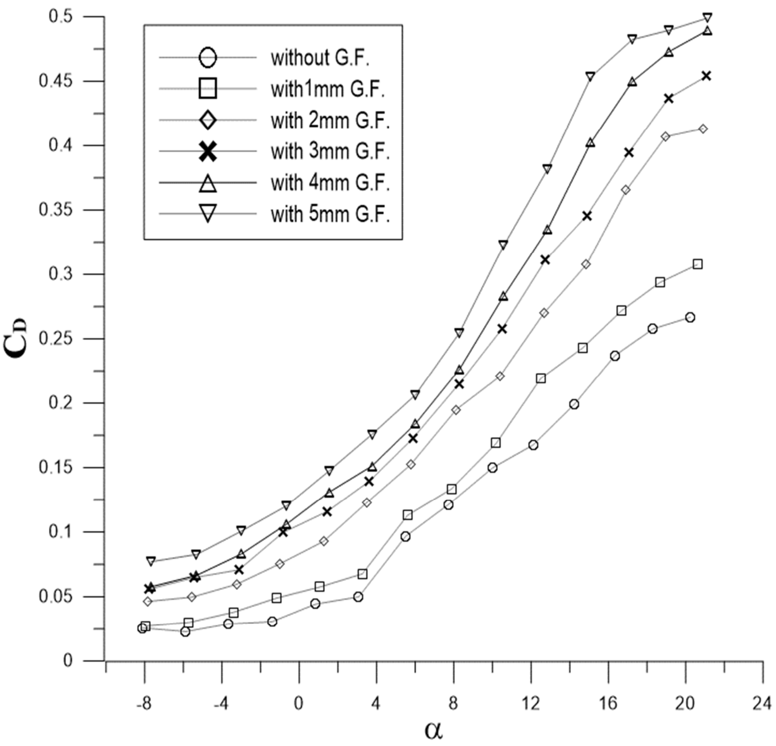

Fig. 6. Drag coefficient (C_D) versus angle of attack (α) for plain G.F.

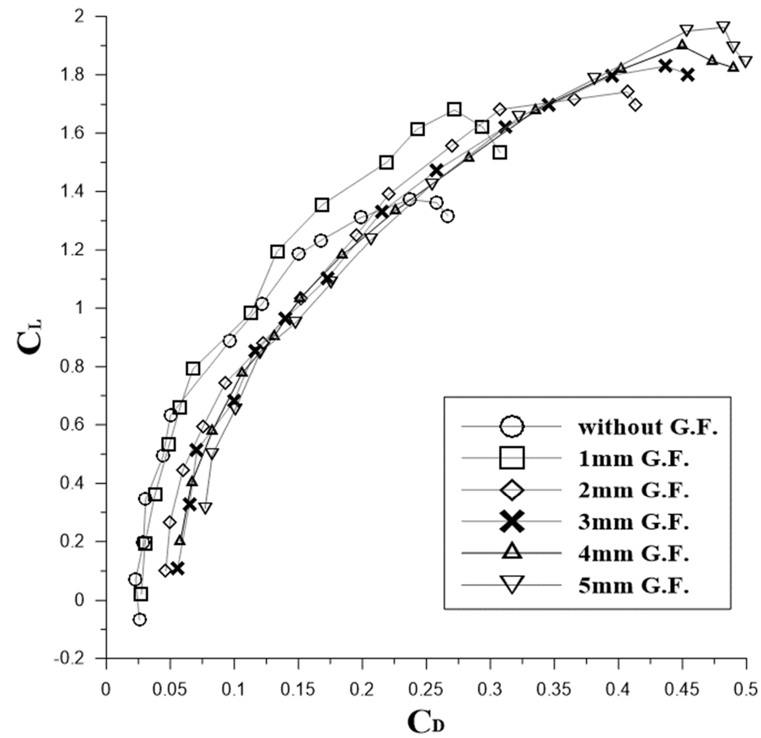

Fig. 7. Lift coefficient (C_L) versus Drag coefficient (C_D) for plain G.F.

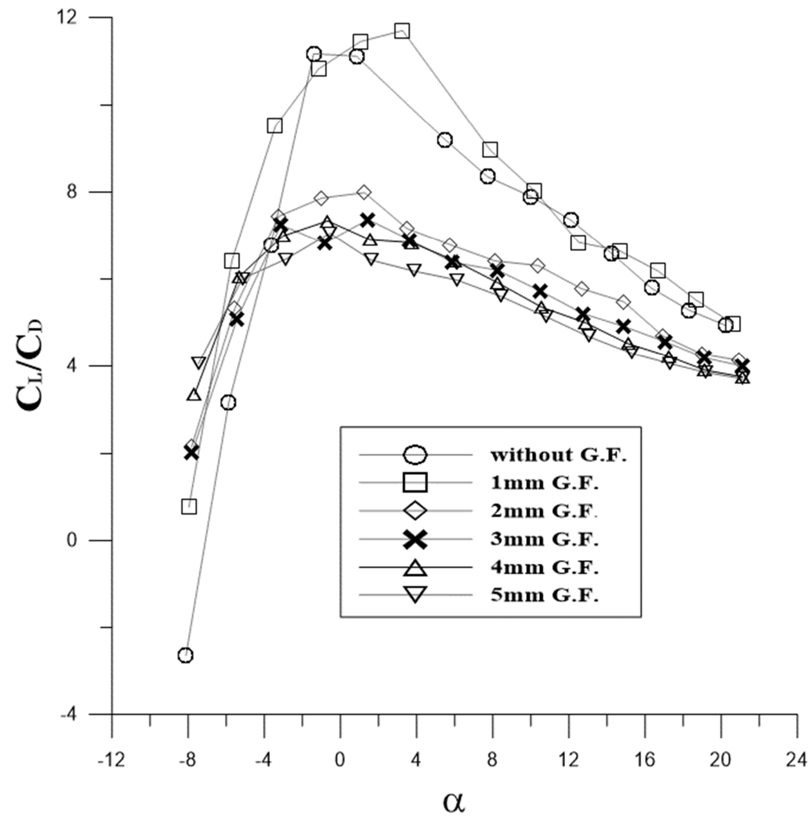

Fig. 8. **Ratio of Lift coefficient to drag coefficient (C_L/C_D) versus angle of attack (α) for plain G.F.**

After review of the plain Gurney flap results it can be clearly show there is an increase in the drag of the plain Gurney flaps proportional with the increase in the Gurney flaps height, the 5mm G.F. has drag higher than other flaps then this flap serrated for width of 2.5mm and 3.5mm in triangular shape with the aim of making drag reduction. Both serrated flap reduce the lift coefficient gained by the 5mm plain flap as in Fig. 9 which shows the lift coefficient against angle of attack for 5mm G.F. and the two triangular serrated Gurney flaps (T.S.G.F.), the 2.5mm serrated G.F. reduce the maximum lift coefficient by (6.63%) experimentally, the 3.5mm serrated G.F. have a (8.51) of reduction. The serration make a remarkable reduction in the drag coefficient as in Fig. 10 Which shows the drag coefficient against angle of attack for 5mm G.F. and the two serrated flap. The 2.5 mm serrated G.F. decrease the drag coefficient by (5%), the 3.5 mm serrated G.F. decrease the drag coefficient by (7.9%). Figure 11 shows lift coefficient against drag coefficient, the figure shows that serrated Gurney flaps shift the polar to the left especially at low and moderate lift coefficient because it reduce the drag coefficient. The 2.5mm and 3.5mm serrated G.F. improve the efficiency of 5mm plain Gurney flaps as in Fig. 12 Which show the lift coefficient to drag coefficient ratio versus angle of attack, it is show that. The 2.5mm serrated G.F. increase the maximum lift coefficient to drag coefficient ratio by (8.45%) and 3.5mm serrated G.F. increase the maximum lift to drag ratio by (15.5%) compared with 5mm Gurney flap.

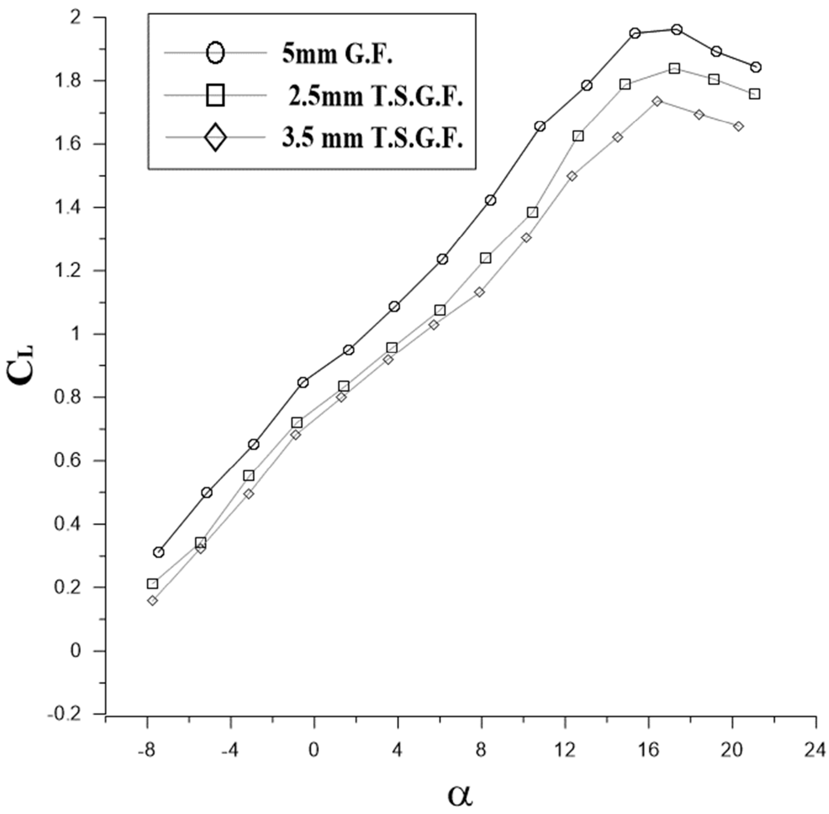

Fig. 9. **Lift coefficient (C_L) versus angle of attack (α) for serrated G.F.**

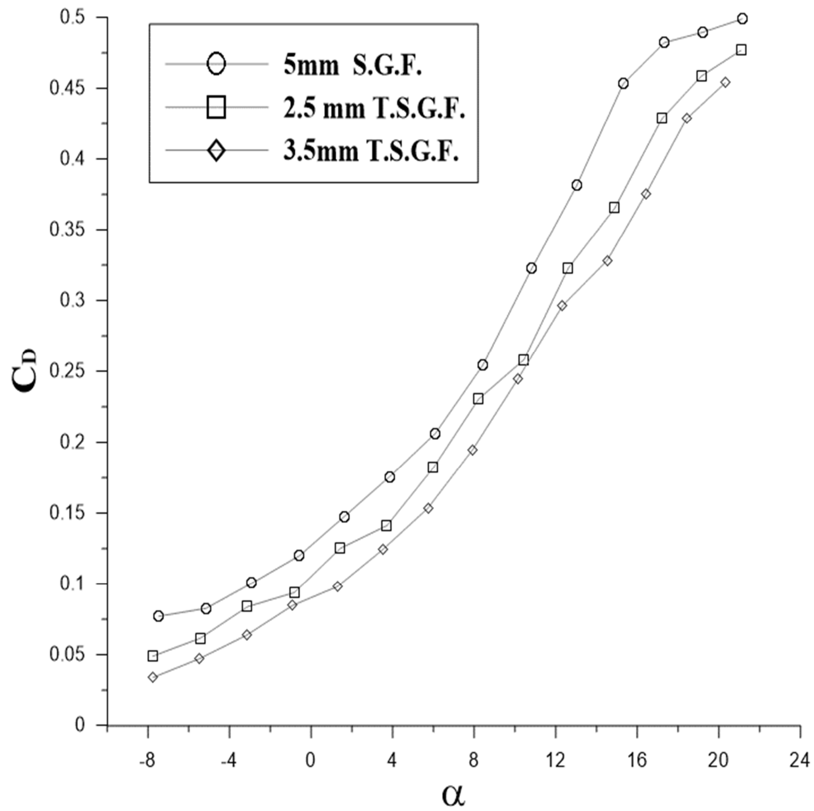

Fig. 10. **Drag coefficient (C_D) versus angle of attack (α) for serrated G.F.**

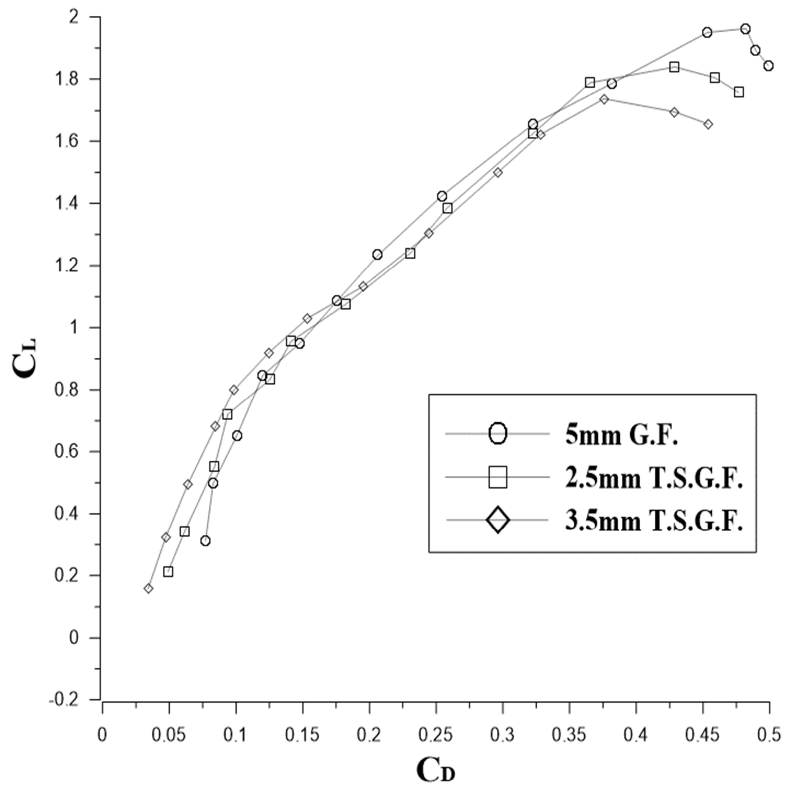

Fig. 11. **Lift coefficient (C_L) versus Drag coefficient (C_D) for serrated G.F.**

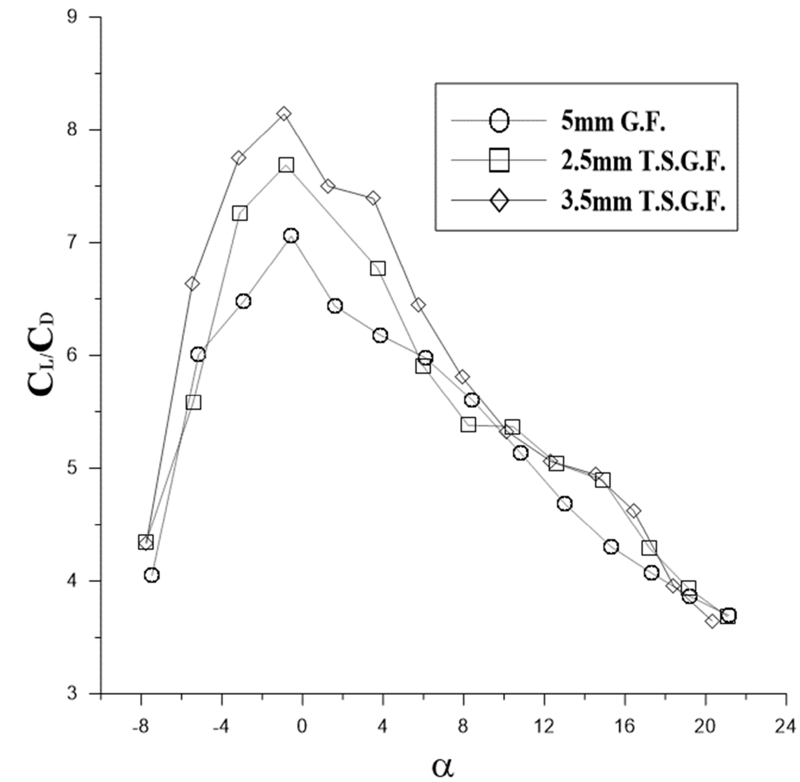

Fig. 12. **Ratio of Lift coefficient to drag coefficient (C_L/C_D) versus angle of attack (α) for triangular serrated G.F.**

After we have better efficiency by 3.5mm triangle G.F. then two configurations have been conducted, the first one is the rectangular serrated Gurney flap (R.S.G.F.) which have (2.5mm×3.5 mm) and the second is a semi-circle serrated Gurney flap (S.C.S.G.F) of 1.75 mm radius in order to see it's effect compare with plain G.F., figure 13 shows the lift coefficient against angle of attack for three different configurations of 3.5mm triangle serrated G.F., rectangular serrated G.F. and semi-circle serrated G.F. compared with plain 5mm G.F., the semi-circle serrated G.F. reduce maximum lift coefficient by (23.4%) while rectangular serrated G.F. reduce it by (26.53%), Rectangular serrated G.F. and semi-circle serrated G.F. reduce the drag coefficient more than triangular serrated G.F., figure 14 shows the drag coefficient against angle of attack for three different configurations of 3.5mm triangle serrated G.F., rectangular serrated G.F. and semi-circle serrated G.F., the semi-circle serrated G.F. reduce drag coefficient by (18%) while rectangular serrated G.F. reduce it by (25%). Figure 15 shows lift coefficient against drag coefficient, the figure shows that serrated Gurney flap shift the polar to the right especially at low and moderate lift coefficient because it reduce the drag coefficient. The semi-circle serrated G.F. and rectangular serrated G.F. has better efficiency than wing with 3.5mm triangle serrated G.F as in Fig. 16 Which shows the lift to drag ratio versus angle of attack, it is show that the semi-circle serrated G.F. increase lift to drag ratio by (28.57%) while rectangular serrated G.F. increase lift to drag ratio by (42.8%) compared with 5mm Gurney flap. From above we find that the most beneficial Gurney flap is not the 5mm Gurney flap, but the 1mm Gurney flap as shown in Fig. 8. This explain why the most beneficial Gurney flap, the rectangular serrated Gurney flap, provides a lift to drag ratio higher than other serrated Gurney flap. The result reveals that the main factor effecting the performance of Gurney flap is not the height but the effective area of Gurney flap.

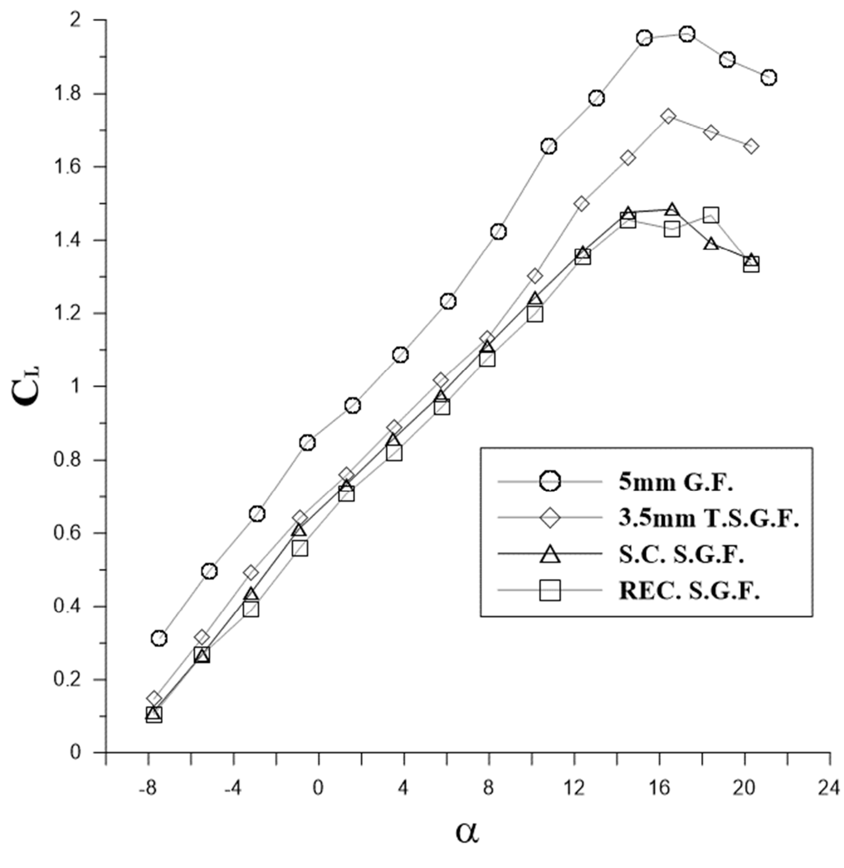

Fig. 13. **Lift coefficient (C_L) versus angle of attack (α) for serrated G.F.**

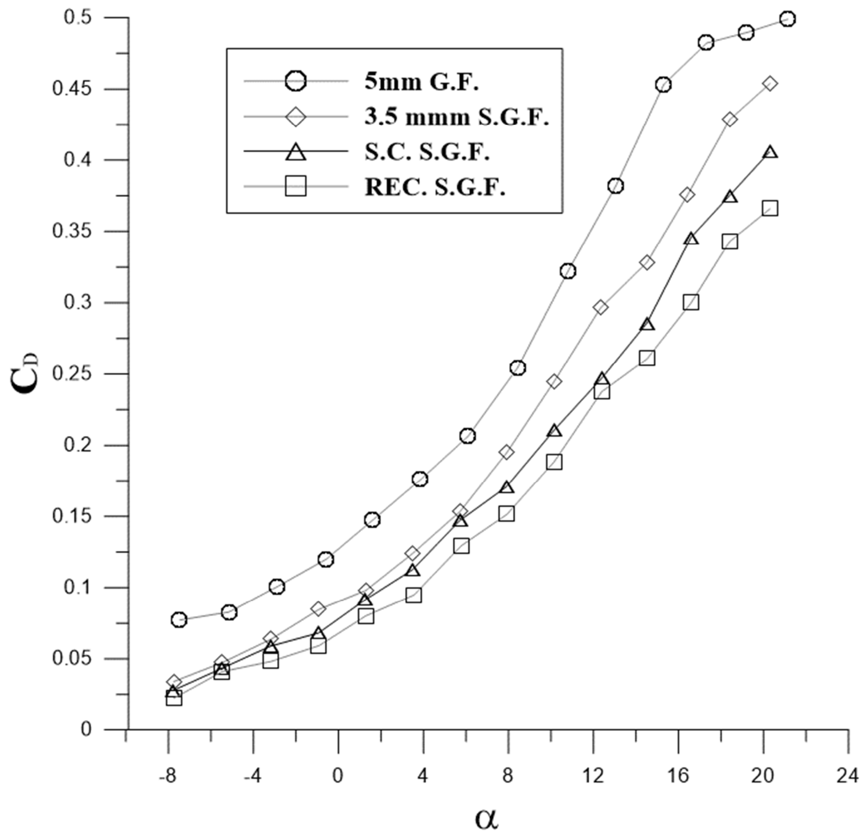

Fig. 14. **Drag coefficient (C_D) versus angle of attack (α) for serrated G.F.**

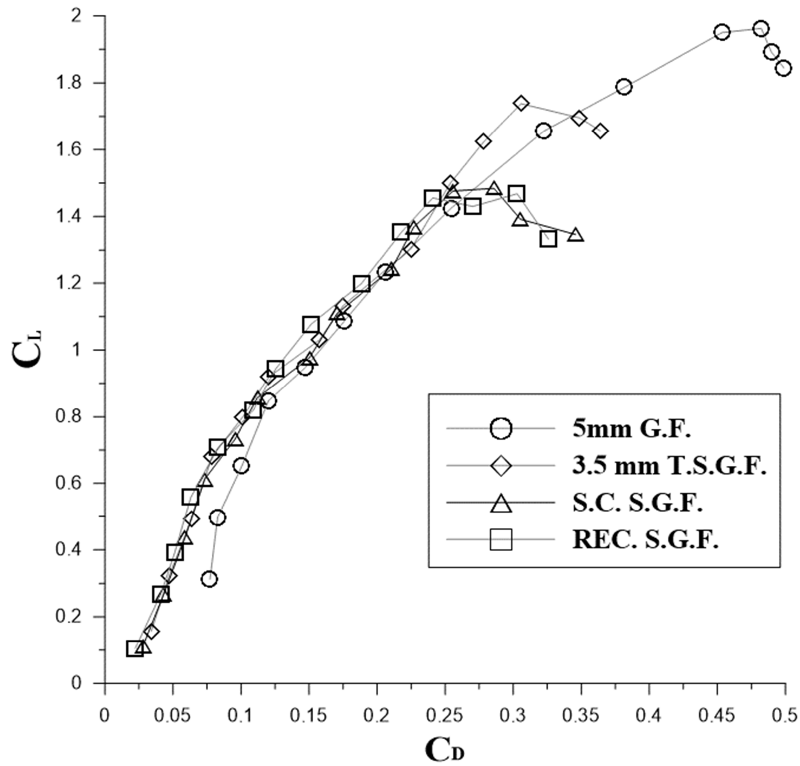

Fig. 15. **Lift coefficient (C_L) versus Drag coefficient (C_D) for serrated G.F.**

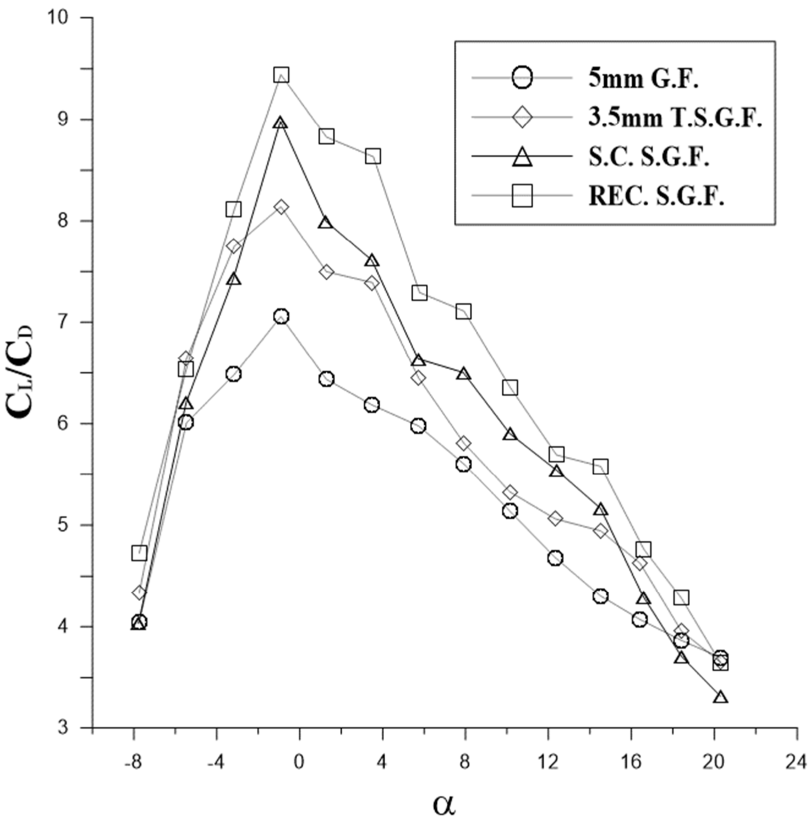

Fig. 16. Ratio of Lift coefficient to drag coefficient (C_L/C_D) versus angle of attack (α) for serrated G.F.

4 CONCLUSIONS

an experimental wind tunnel investigation was undertaken to determine the effect of Gurney flap on the aerodynamic characteristics of Clark y-14 airfoil wing at a Reynolds number of $2.1x10^5$ at (35.7 *m/s*).The Gurney flap improve performance of Clark y-14 airfoil wing compare with clean wing ,the Gurney flap increase lift coefficient decrease stall angle slightly and increase drag coefficient ,the most beneficial Gurney flap is about (1mm) which increase maximum lift to drag ratio to (5.31%) compared with clean wing . The 2.5mm serrated G.F. increase the maximum lift coefficient to drag coefficient ratio by (8.45%) and the (3.5 mm) triangular serrated Gurney flap improve lift to drag ratio by (15.5%) compared with (5mm) non serrated G.F., the semi-circle serrated G.F. increase lift to drag ratio by (28.57%) while rectangular serrated G.F. increase lift to drag ratio by (42.8%) compared with 5mm Gurney flap., from these result we concluded that the serration improve lift to drag ratio but it is effect still weaker than 1mm G.F. and 1mm G.F. only the improve lift to drag ratio compared with clean wing. The result reveal that the main factor effecting the performance of Gurney flap is the effective area of the Gurney flap.

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