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Investigating the Effect of a Single Gurney Flap Heights on Airfoil

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Abstract. : In the present investigation, the effect of different Gurney Flaps (GF) heights ranging from 0.25% C to 5% C on the performance of NACA 0012 is analyzed and the optimum is chosen from this investigated height. Use to estimate the flow structures around the airfoil turbulence model k-ω (SST) shear stress transport equations are employed. The present results showed that gurney flap improves not only the lift but also increases the ratio of lift to drag ratio at the different angles of attack ranging from 2°,4°,6°, 8°, to 10°.

The pressure distribution around the airfoil is presented which is useful to comprehend the technique of gurney flap on airfoil aerodynamic performance. Moreover, it is found that the increase of airfoil drag with gurney flap can be Increase to the increase of pressure drag between the windward and the leeward sides of the gurney flap itself. the tide of a gurney flap for a height of 1.5% chord at the trailing edge give the optimal performance as the lift to drag ratio increased at all angles of attack consequently; therefore it is recommended to install GF with a height of 1.5% chord to the trailing edge to obtain maximum lift enhancement with a minimum drag penalty

Keywords: Heights of (GF), Flap, Lift enhancement, pressure distribution, airfoil, Computational Fluid Dynamics.

1. INTRODUCTION

The utilization of wind energy has witnessed impressive development as a major source of clean energy, which is one of the most important forms of renewable energy. One of the main components a wind turbine its blades that in turn capture wind energy, while the airfoils are the basic elements of the blade. A large number of researchers are interested in how to improve the aerodynamic properties of the air wing, as it has a major impact on wind turbines and increases their overall capacity by catch winds. Utilization gurney flap as one of the ways that can significantly change that aerodynamics Properties of airfoils. Later, researchers from different countries conducted a large of researches on the mechanisms and the effects of the gurney flap height using wind tunnel tests and numerical simulations. The Gurney Flap (GF) can be defined as a short plate that is fixed at the trailing edge and vertically on the chord line on the pressure side of the airfoil, the schematic of a GF for airfoil is shown in Fig 1. The first experimental study on the installation of GF at the back edge of the airfoil is carried out by lie-beck [1]. This research found that it can increase the value of lift an airfoil using the gurney flap. X. He et al. [2] In this study, the enhancement of the lift of the G. f to an airfoil is investigated at a low Reynolds number with numerical simulations, at different heights from range from 0.25% C to 3% C respectively. Myose et al. [3] Wind tunnel tests are conducted at low velocity on aileron NASA 0011 with different heights from the Gurney Flap which ranged from 1% to 4% chord ,is found the G F increases suction on the upper surface and reduces surface pressure, which increases the lift. Nengsheng Bao et al [4]. An experiment is conducted to verify the improvement the lift of airfoil two-dimensional with a small plus edge Flap in a low speed closed wind tunnel. The NASA 632-215 and the Reynolds number 2.4 × 105 are selected on the airfoil chord. In experiments, the angles of attack varied from 0° to 40° and the heights of the Flaps are 1.0%, 1.5%, 2.0%, and 2.5% of the airfoil chord. The effect of various deviation angles (0, 45, 90, 135) is compared and studied at the trailing edge of the Gurney Flap. The results obtained in this research also included getting the best performance increase and the best height is 2% c when the angle of the back edge is 90^0on the airfoil tendon. Jain et al. [5] to verify the results, the Baldwin-Barth disturbance model is used to solve the single equation for the mathematical analysis of the GF on the NACA 4412 airfoil. It concluded that the increase in the lift resulting from the change of the height of the GF is accompanied by an increase in drag. The researcher suggested that the height of the Flap is less than 1.25% of the tendon leading to an increase in Lifting with a very slight increase in clouds, and the separation point of the flow moves backwards, the higher the GF. Fernandez-Gamiz et al. [6] the study presented the extent of the effect of the change in the heights of the GF, and the conclusions showed that the shape of the airfoil has a decisive effect on the dynamic performance of the antenna of the airfoil with the GF. Gigure et al. [7] explained that the effective effect of the height of the GF does not exceed the thickness of the boundary layer. Wang, J. J. et al [8], examined the high lift component of Gurney folds or their motivations of low-speed airfoils, excessively basic airfoils, lifting units for low-speed airfoils, the results from the GF height. Vieira et al [9] discuss the effects of Gurney Heights and the aerodynamic properties on five variable airfoils, displaying so much the lift-increasing effects of variable Gurney Flap heights and installation locations for different airfoils are not the same. Hexi et al. [10]; is investigated that the GF lifts enhanced at low Reynolds number with numerical simulation, with Flap heights varying from 0.25% to 3% C. The researcher discussed the impact of G F on the airfoil in terms of drag coefficient, flow field, and pressure distribution. GIGUERE et al. [11] studied the influence of GF, the height of which ranges of 0.5 to 5%C. The test is carried out on two different types of airfoils, LA203A and Gottingen 797, when Reynolds number 250,000 is considered relatively low, founds GF that reduced the drag value and increased the lift value and considered the optimum length of GF is measured by the boundary layer thickness. STORMS et al [12] the researchers found pressure distributions on the airfoil with the GF, they also found that during high lift transaction there is less drag, but with higher drag performance, the lower lift performance factor results.

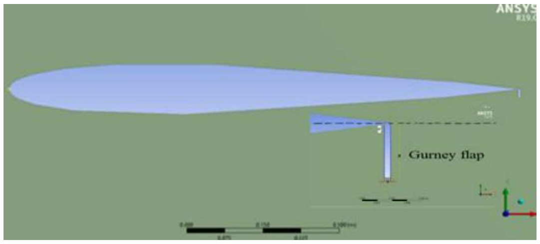

Fig. 1: schematic drawing GF and length ‘H’ with trailing edge from the chord.

In current work the influence of changing of GF heights with the following values of 0.25, 0.5, 1, 1.5,2,3,4 and 5 % chord is studied at different attack angles from 2^0 to 10^0 at Reynolds number 10^6 and analyze its ability to ameliorate the aerodynamic characteristics of the NACA-0012 airfoil, thus improving the aerodynamic performance of airfoil, the optimum is chosen from among these heights

2. Numerical Analysis

In this investigation numerical simulation using Ansys Fluent software with a 2-D k-ω (SST) turbulence model is carried out on NACA 0012 airfoil of 1m chord length (C) with the attachment of GF at the trailing edge. Figure 2 illustrated the difference between the trailing edge at the clean airfoil and airfoil with the attached GF. C-type domain and grid are created using ICEM CFD, with far-field boundaries of 25 Chord length and 50 Chord length upstream and downstream the airfoil respectively as illustrated in Figure 3. As the study is focused on the airfoil, the Fine mesh has been used in the layer around both airfoil and Flap, while a coarse mesh has been used for the rest flow in the tunnel as illustrated in Figure 4.concerning the border conditions, adiabatic and no-gliding conditions are used at the wall. At the tunnel inlet, the Constant speed with variable flow direction component depending on the angle of attack is set. At the outlet, the pressure is set to absolute zero (Pascal).

The pressure field is linked to velocity through the SIMPLE (Semi-Implicit Method for

Pressure-Linked Equations) pressure-velocity coupling algorithm. For momentum turbulent kinetic energy, and eddies dissipation rate second-order upwind discretization scheme has been used. Turbulence intensity of 5 % is set for both inlet and outlet boundary conditions as the flow at this level of turbulence intensity is considered fully developed.

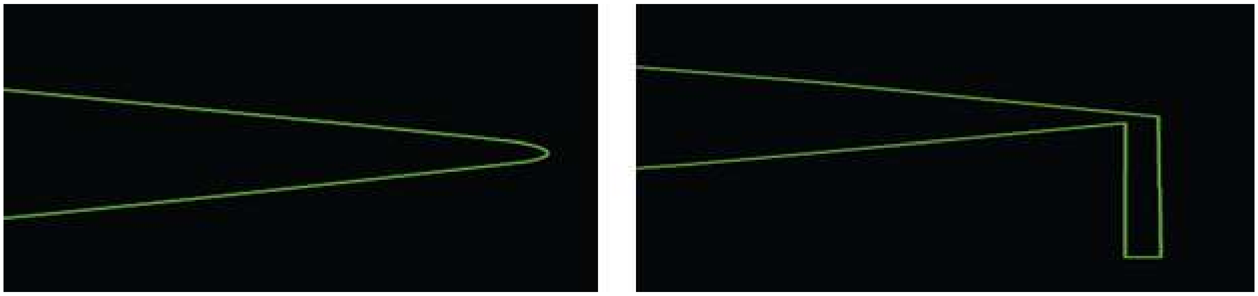
(a) Without GF (clean airfoil) (b) with GF

Fig2: Trailing edge of NACA-0012; a) without GF, b) with GF.

3. Mesh independence

Grid independence test is done to ensure that the results did not depend on the number of elements as indicated in Table 1. This test is done for each GF heights separately before performing the runs. The domain of dimensionless wall distance (y+ plus) lower than 1 for the first grid point above airfoil surface From Table 1, a very slight change at lift and drag coefficient is observed by increasing the cell number over 17500 from standard to fine mesh, whereas, increasing the number of elements over this value, the solution takes a long time without tangible improvement in its accuracy.

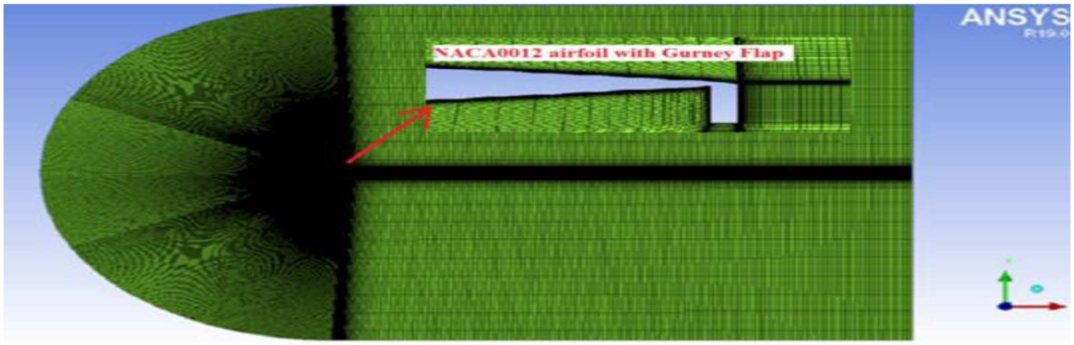

Fig3: Computational domain of NACA0012 Airfoil with GF.

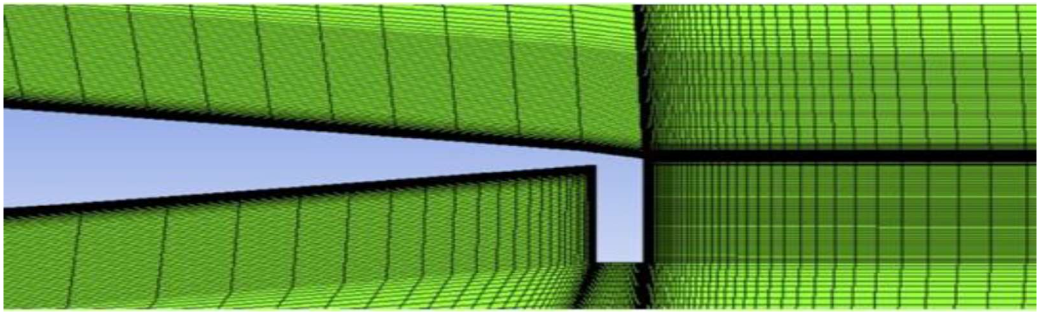

Figure 4: Zoomed view of mesh near the airfoil trailing for GF.

Table 1: Assessment of Grid test

Mesh	Cell numbers	C_l	C_d
Coarse	55000	1.0571631	0.02856436
Standard	195000	1.1059042	0.01518304
Fine	550000	1.1053976	0.01508356

4. CFD Model Verification

The Verification procedure examines whether the materialistic models utilized in CFD simulations commensurate for the veritable condition. The requisite investigation or validation plan is to identify and quantify the fault during the comparison of experimental results with simulation or numerical sol data

In the present study, verification is done on the NACA 0012 airfoil with single GF (height = 2 % c and width = 5 mm) at $R_e = 10^9$. The experimental results for GF published by Wang et al, [14] are relied upon in comparing the Lift and drag coefficient calculated from the present CFD model.

Where the maximum error for all calculated results for lift and drag is are 10.5 % and 13.9 % respectively compared with experimental data [14]. From Figures 5 and 6, the present CFD simulations agree pretty well with the experimental published data. As the highest deviation obtained is 12 % for the drag and 8% for lift coefficient, it can be considered an acceptable deviation.

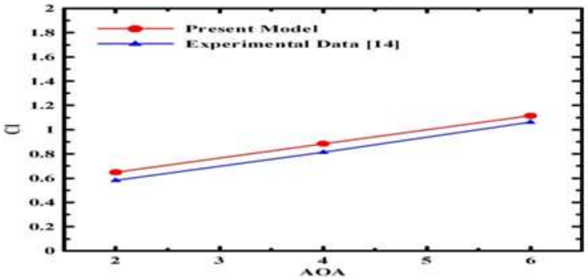

Fig 5: Comparison of Present Lift Coefficient for Single GF Airfoil with Experimental Data [14] at Re=10^{9}.

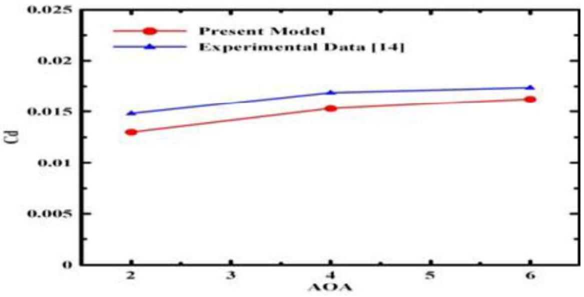

Fig 6: Comparison of Present Drag Coefficient for Single GF Airfoil with Experimental Data [14] at Re=10^{9}.

5- Result and dictation

The result shows that the effect of GF height which ranges from 0.25 %C to 5 % C on the performance on NACA 0012 at Reynold number of 10^6 and different attack angles will be discussed. Figure 7 displays the effect of the GF altitude changing on the aerodynamic lift coefficient of. It is evident from the Figure 7 that the lift coefficient growing progressively with the boost of GF heights from 0.25% to 5% c in the range of attack angles from 2^0 to 8^0. These results also indicate that impact of GF is to growing the efficacious camber of the airfoil and the shifting of the location of the rear stagnation point.

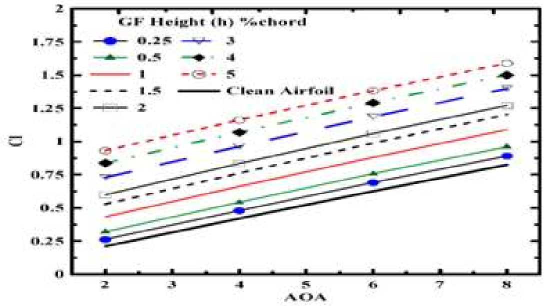

Fig 7: Lift coefficient versus angle of attack at different GF heights.

At the angle of attack (A0A = 6°) , The lift coefficient (Cl) is increased by 10.24 , 20.96, 40.66 ,57.68 ,68.83 ,89.42 ,106.10 and 120.65 % , for the different heights G F 0.25/0.5/1/1.5/2/3/4and 5% respectively compared to clean airfoil.

Figure 8 shows the variation of drag with angles of attack at various Gurney Flap altitudes distinctly, As the GF heights increases, the drag coefficient increases gradually are the highest drag coefficient at the largest GF heights of 5% C. at the angle of attack 6, drag coefficient (Cd) is increased by 13.26, 18.27, 30.06, 29.85, 58.03, 90.60, 126.49 and 165.55 % at the various heights G F 0.25, 0.5, 1, 1.5, 2, 4 and 5% respectively compared to clean airfoil. Thus, at large GF height compared to the increase of lift, drag has a clear and important impact.

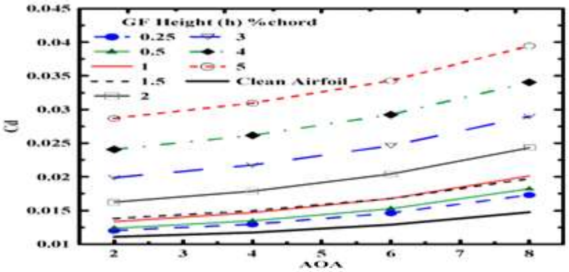

Fig 8: Illustrate the drag coefficient with angle of attack at different GF heights

Most of the former studies that are carried out to improve the aerodynamic performance of the airfoil are aimed not only at increasing the lift coefficient but also to decrease the drag coefficient, and therefore the most important goal is to maximize the lift to drag ratio.

The variation of lift to drag ratio with attack angles at different GF heights are as illustrated in Figure 9. It can be seen from the Figure that at low attack angles of 2 and 4 the L/D ratio increases for all GF heights increase compared to clean airfoil.

Whereas, with the L/D ratio decreases, as the GF height increases to 3%, 4 % and 5 % at the angle of attack 6.Where the increase in lift coefficient due to high GF heights of 3%, 4%, and 5 % comes at the expense of increasing the value of drag. This is in concord with Liebeck [15] they found that when the G F heights are greater than 2% chord, the drag coefficient increases dramatically.

A summary of the percentages of increase or decrease in the L/D ratios for all GF heights at attack angles ranging from 2° to 10° is showing in table 2. The installation of Gurney Flap with a height of 1.5 % chord at the airfoil trailing edge gives an optimal performance, in this case, the lift to drag ratio can be increased by 100.44 %, 41.70 %, 21.43 %, 9.30 %, and 1.08 % respectively. As the L/D ratios increase compared to the clean airfoil by the following percentages 100.44 %,41.70 %,21.43 %,9.30 %, and 1.08 % at an angle of attack of 2°, 4°,6°, 8°, and 10° respectively.

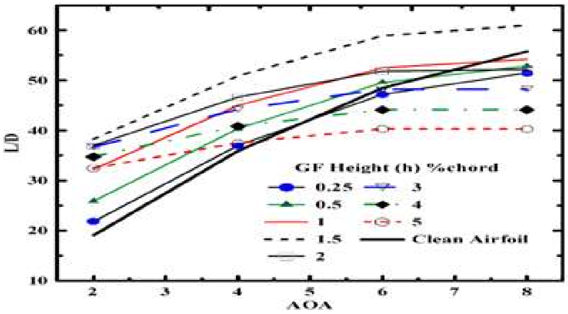

Fig 9: variation of Lift to drag ratio with the angle of attack at different GF heights.

Figure10 illustrates the variation of the L/D ratios with the lift coefficient at different Flap heights. At low-to-moderate lift coefficients, there is a drag penalty associated with the GF which increased with Flap height. The lift to drag ratio increases significantly at high lift coefficients. As a result, the impact on the maximum lift-to-drag ratio is teeny. However, the lift coefficient for the given lift to drag ratio (L/D) is increased significantly.

It can also be observed that the attachment of GF with a height of 1.5% C provided L/D ratio greater than the clean airfoil when the lift coefficient overrides 0.90 and the extreme increase of L/D approximate 60.96 %, is obtained when the lift coefficient is around 1.2.

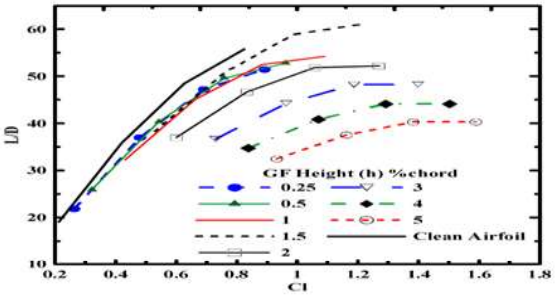

Fig 10: Illustrate the Lift coefficient with Lift to drag at different GF heights.

Table 2: Percentage of Increase in L/D ratio for different heights G F Cases Compared to Clean Airfoil.

Gurney Flap Height (% of the chord)	A different angle of attack with the L/D ratio				
	2°	4°	6°	8°	10°
0.25	14.4%	3.1%	-2.7%	-7.7%	-13%
0.5	35.8 %	12.4 %	2.8 %	-5.6 %	-12.1 %
1	69 %	25.3 %	8.15%	-2.8 %	-12 %
1.5	100.4%	41.7%	21.4%	9.3%	1.1%
2	93.6 %	29.9 %	6.8 %	-6.4 %	-16.6 %
3	92 %	23.2 %	-0.6 %	-13.5 %	-23.2 %
4	82 %	13.8 %	-9 %	-20.9 %	-58.6 %
5	70 %	4.5 %	-16.9 %	-27.8 %	-93.8 %

Generally, attachment of G F on the trailing edge of the airfoil can increase the L/D ratio since it raises the pressure on the lower surface of the airfoil at a location upstream of the Flap [1]. However, at a low angle of attack, the lift-to-drag ratio may become smaller since the G F may block the flow from moving downstream and therefore increase the drag.

To explain what happened due to the presence of the G F, the pressure distribution over NACA 0012 with and without GF at an attack angle of 6° as illustrated at figure 11. It is evident from the figure that the presence of the GF increased the suction with a significant value over the upper surface, which is represented by the large decrease in pressure with corresponding to clean airfoil, while we notice a slight decrease in pressure on the lower surface. This influence increases the pregnancy capacity an airfoil with GF is higher than the clean one, which leads to an increase in the lift coefficient. The larger the GF height is, the more the lift enhancement, the air flows smoothly along the upper surface the of airfoil without separation.

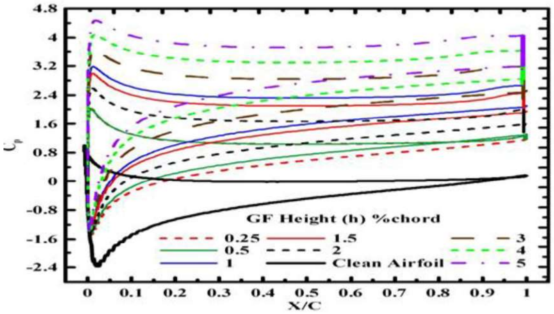

Fig11: Pressure Distribution over NACA0012 for different heights of GF at A0A= 6^{0}

6- Conclusions:

The verification of the CFD model with experimental data is carried out and showed, in general, a fair agreement. The maximum deviations between the present numerical results and the experimental results of [14] are about 8 % and 12 % for lift coefficient and drag coefficient respectively, it can be considered an acceptable deviation.

The effect of GF has been studied at angles of attack range from 2 to 10 and wind speed 15 m/s ($Re=10^{6}$) and the following has been concluded. Both lift and drag coefficient increases gradually with the increase of GF height from 0.25% to 5% c at all angle of attack. Through an analysis of the results and their comparison with each other, it is also found that when the height of the G.F increases over 2%c, it results in a decrease in the overall performance of the airfoil due to the increase in the value of the drag, and the best results are in the overall performance of the lift to drag ratio compared to the clean airfoil the optimal height of the GF at 15% c for NACA 0012 the improvement rate percentages 100.44 %,41.70 %,21.43 %,9.30 %, and 1.08 % at an angle of attack of 2°, 4°,6°, 8°, and 10° respectively.

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