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# Gurney Flap Studies on Lift and Drag of an Aero foil Naca0012

[1] Manjunatha Patil, [2] Mr.Jatadhara, [3] Dr,V.Ramesh
[1] Student, M.Tech, SIT, Tumkur
[2] Assistant Professor, Mechanical Engineering Dept., SIT, Tumkur
[3] Joint Head, CTFD Division NAL, Bengaluru,India

**Abstract: -- In this performance we have executed the computational analysis on aerofoil to determine the effect of gurney flap on lift and drag performance of naca0012. A Gurney flap is a flat plate of order from 1 to 2% of the aerofoil chord length, aligned vertically to the chord length and positioned on the aerofoil pressure side at the rear end. This work involves a steady state, in-compressible Navier-Stokes equation solver and two dimensional CFD calculations for subsonic flow over a naca0012 aerofoil at different angle of attack and maintained at high Reynolds number at 3x are conferred using the unique equation spallart-allamaras turbulence model. Adopting a 3.0% chord length Gurney flap enhances the coefficient of lift gurney flap height preferred. The computed solutions display the detail picture of the flow system at trailing edge and give a feasible evidence for the enhanced aerodynamic function. The computational results describe the details of the flow nature at the trailing edge and provide feasible information for the increased aerodynamic performance**

**Keywords: Aero foil, Reynolds number, Angle of attack, Lift and Drag.**

## I. INTRODUCTION

Through the years, high-lift equipment's have draw thought of airplane engineers and manufacturers as one can develop landing and departing mechanism of airplane through aerodynamic system. Flaps are similar airplane devices for lift enrichment, where trailing and leading edge slotted flaps are frequently used in almost all airplanes. Flow over these equipment's is very problematic because it involves boundary layer separation, wake regions, outward flow on boundary layer at the flap socket, which creates vertex flow over the boundary layer. This make the modification of high-lift equipment's very complicated. Due to this, manufacturing difficulty and high cost, high enforcement airfoils can't be used in military and economic airplanes. Even if it possible, high-lift equipment's can't fit the normal work fully often Hence, it is a usual tradition to adopt a simple equipment such a thing Gurney flap (GF) leads to enhancement of aerodynamic characteristics of aircraft.

The GF is a small flat plate adjusted to the wing rear end vertical to the line of chord on the windward side of the aircraft. It is considered as lift enrichment equipment in aircraft so it has wide range of application. Race car trainer Dan Gurney developed GF on an introvert wing to enhance the descending force, hence enriching the contraction while speeding up, control and intersection. Due its quite design have attract many aeronautical engineers, designers and aircraft development industries.

The gurney flap intensifies the lift by varying kutta condition at rear end. The vertex which are more readily yield in von Karman vortex street in extension to this interval eddies yield back of the flap, chord wise eddies yield from leading side of flap become critical at higher angle of attack therefore gurney flap enhances the maximum coefficient of lift and decline the angle of attack due to this low angle of attack decrease in drag appear. Flaps are applied to obtain high lift for an airplane wing at certain speed. It can be fixed or movable on the trailing edge of aircraft wing. Flaps are benefit during departing when it needs high lift and during landing it cause an increase in drag so it can be retract when not useful. Spanning the flap leads to increase in camber of wing and coefficient of lift by decreasing stalling speed.

High-lift equipment is slat, a small aerofoil like equipment fitted in front of aerofoil trailing edge. The slat alters the flow of air from the trailing edge, passing it to flow evenly over the aerofoil upper surface at a higher angle of attack. This provides the aerofoil to be performed completely at the high angles needed to generate high lift. It may be stationary at its position or movable or it can be protractible so that the socket is locked when not needed. If slot is locked, then slat may look as a usual part of the trailing edge of an aerofoil. Bigger modern aircraft adopts the double socket flaps to generate the extreme lift needed during aircraft depart. A slat be allowed either full span, or

 

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Vol 2, Issue 5, May 2017

can be placed on trailing section of aerofoil which depend on lift aspects demand to be adjust for least control. For least angles of attack the flow of air through the slot is negligible, despite it subsidize to drag. At deliberately high angles of attack, the airflow through the slot becomes significant.

## II. LITERATURE SURVEY

The study on Gurney flap was first reported by Liebeck,(1978), 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. Lie beck 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. It was published in 1978 at international journal of innovation and scientific research.

Wadcock et al, (1987), performed wind tunnel tests at a Reynolds Number of 1.64 × 106 on a baseline NACA4412 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 the Gurney flap was extended beyond about 2% of the airfoil chord length, at which point the flap extended beyond the boundary layer thickness. It was published in 1987 at International Journal Of Mining, Metallurgy & Mechanical Engineering (IJMMME).

Giguere, P. et al, (1995). Quantified 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. It Was Published In 1995.

Wang et al (2006), 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. It was published in 2006 at gurney flap on a simplified forward swept journal of aircraft.

The experimental and computational study performed by ross et al, (1995), to determine the effect of gurney flaps on two-element naca 632-215 mod b airfoil. Jang et. Al.( 1992), 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. It was published in 1995 at lift enhancement device journal of aircraft.

Chen et al. computationally investigated the effects of square, round, and smooth convex configurations of the GF in low solidity low-pressure turbine cascade and found the round configuration to be most effective to decreasing the adverse pressure gradient by increasing the flow turning angle and reducing the flow losses in low-solidity cascade. T strip is found to increase the slope of lift curve without any shift in zero lift angles by Cavanaugh et al.

Myose et al. performed some low speed tests in the wind tunnel for NACA 0011 airfoil with Gurney flap lengths varying between 1-4% of chord length.

They reported that the increase in upper surface suction and lower surface pressure provides an increment on lift force.

Singh et al. studied Gurney flap with on NACA 4412 and 0011 airfoils by solving two dimensional Navier Stokes equations. Jang et al. also solved the Navier- Stokes equations for NACA 4412 airfoil with Gurney flap.

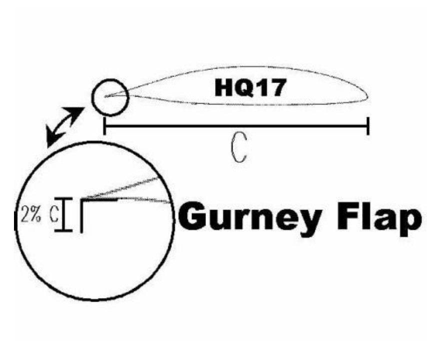


*Fig1. Gurney flap configuration*

## III. COMPUTATIONAL ANALYSIS

Computational Fluid Dynamics (CFD) is a mathematical approach used to analyses physic behind the flow problems with help of standard flow solving equations.

 

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(IJERMCE)
Vol 2, Issue 5, May 2017

The CFD system uses standard boundary condition, basic equation which is made in terms of grids and representing geometries. CFD is numerical approach based on simulation technique in which the fluid governing equations namely continuity, momentum and energy are computed to gratify applied boundary conditions.

***Geometry Modeling and Grid Generation:***

The geometry taken for analysis of Gurney flap is 4-digit NACA aerofoil series which is NACA0012. In this series NACA0012 aerofoil is symmetrical, the 00 represents that has no camber and 12 indicates aerofoil has a 12% thickness to chord length ratio means it is
12% as long as its thickness and having 1m chord length. Computational simulations were carried out for Gurney flap sizes from 1% to 3% chord length, with flap placed on adverse pressure side of aerofoil at trailing edge. For NACA0012 aerofoil simulations were computed by using a C-grid domain as shown in fig 1. The domain divided into bottom an top far field boundaries which are 12 chord lengths away from aerofoil trailing edge. The downstream and upstream boundaries also 12 and 11 chord length away from aerofoil respectively. The grid was generated by using GAMBIT software. The fig 3 shows closer vision of grid at locality of aerofoil.
The resolution of the mesh is greater in regions where greater computational accuracy is needed, such as the region close to the airfoil. The y+ distance is of the order of 1 for the first grid point above the airfoil surface. Present simulations used a C-type grid topology with 11800 elements that is presented in figure 4.

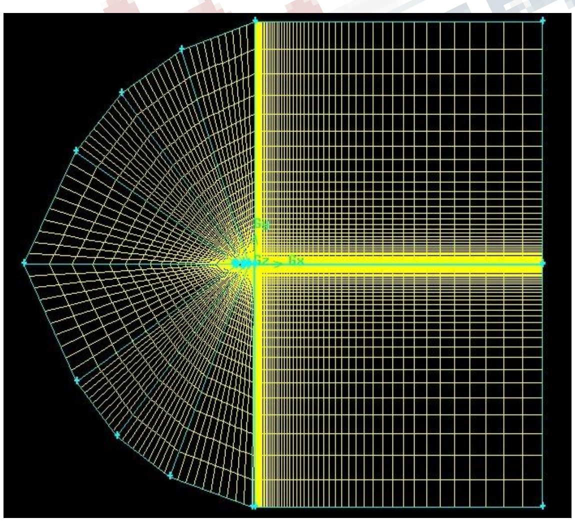

***Fig2. C-Grid Used for NACA0012***

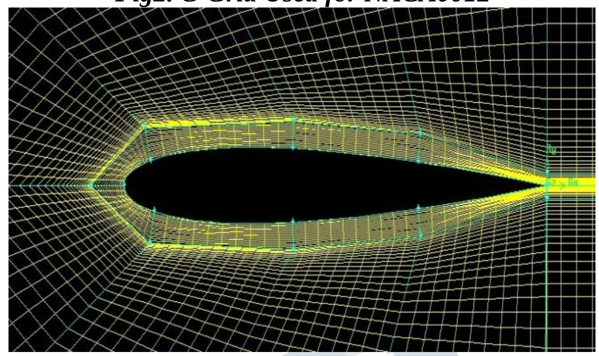

***Fig3.Close Up of Grid in the Vicinity of NACA0012***

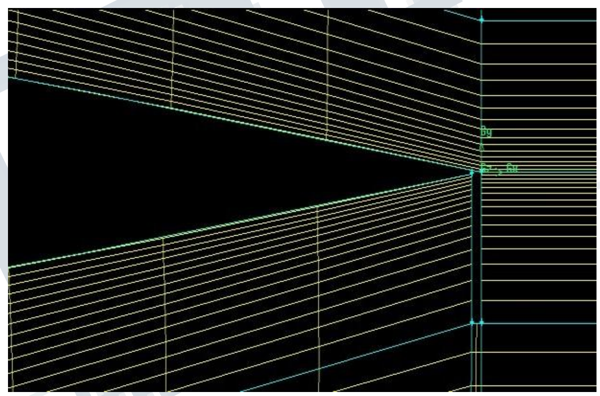

***Fig4. Close up of Grid in the Vicinity of Gurney flap***

Boundary conditions and fluent solver setting Assigning the properties to different geometries is crucial step to carry the simulation technique. In this problem, the boundaries of generated mesh were set to the x and y components of velocity, inlet of aerofoil assigned as "velocity inlet" with recommended $x=V\cos(\alpha)$ and $y=V\sin(\alpha)$ on front side of mesh. The rear far field boundary condition is assigned as "pressure-outlet" to solve the problem with the zero gauge pressure. The aerofoil and Gurney flap both assigned as wall type boundaries. Mainly air is considered as fluid so standard density of air and laminar viscosity of air has taken into considerations.

These models were run in fluent by RANS solver at high Reynolds number with free stream velocity. The section of NACA0012 formed as no-slip wall condition even with gurney flap also assigned to no-slip wall surface. The thickness of gurney flap doesn't affect much during grid generation so any negligible thickness would be preferred. The first order upwind is utilized for

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computing the transport variables for turbulence model. Under relaxation factor is set to be 0.8 for Spalart-allmaras turbulence model. Solution initialization is computed from inlet velocity followed by appropriate number of iterations to undergo solution convergence. These equations are solved up to convergence criteria about for every residual to get converged.

| INPUT | VALUE |
|---|---|
| Reynolds Number, R | 3*e-6 |
| Mach Number, M | 0.3M |
| Free stream velocity, V | 102.96 m/s |
| Density of fluid, ρ | 1.225 kg/m3 |
| Turbulence Model | Spalart-allmaras (SA) |
| Angle of Attack, α | 0 to 14 degree |
| Convergence Criteria | 10e-5 |
| Fluid | Air |

## IV. RESULTS AND DISCUSSIONS

In this study, computational simulations were carried out to determine the Gurney flap effect on the lift and drag coefficients and pressure distribution over the aerofoil are computed by analysis through FLUENT algorithms for the specified boundary specifications. The simulated results obtained from computational methods were compared with experimental results.

***Effect of Height Of Gurney Flap On Co-efficient of Lift:***

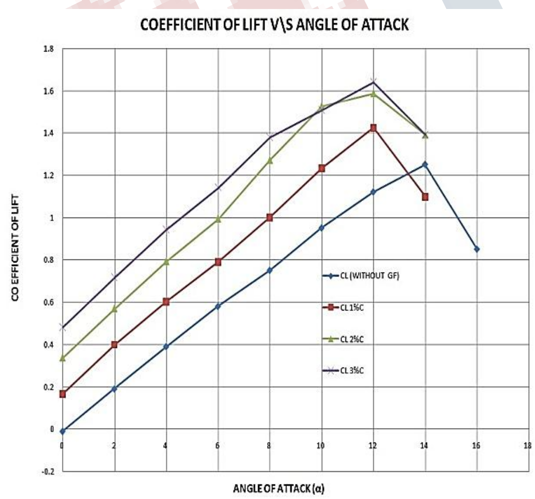



***Fig5. Lift coefficient verses Angle of attack***

The deviation of coefficient of lift with different angle of attack is shown in Figures. The curves for coefficient of lift corresponding to heights of Gurney flap with 0%C (without GF), 1%C, 2%C and 3%C are represented. Spalart-allmaras turbulence model used for simulation, it is in FLUENT software. In comparison with clean airfoil at a specified angle of attack 10 degree increase in lift coefficient for 1%, 2% and 3% of flap height is 34%, 54%, 62%, respectively.

In normal, the coefficient of lift increases as size of Gurney flap increases for a specified angle of attack. In this case, a 1% c height of Gurney flap alters the lift curve by some means of 2°, but the link between the height of Gurney flap and lift- curve alter does not looks to be straight. Particularly, the raise in coefficient of lift due to modifying the Gurney flap height from 0% to 1% chord is more than the changes create by modifying the flap from 2% to 3% chord. The figure also shows that for zero angle of attack lift appears to become ever more pessimistic as a bigger Gurney flap is used. These outcomes propose that the Gurney flap causes rise in the effective camber area of the aerofoil.

Effect of Height Of Gurney Flap On Co-efficient of Drag: The variation of coefficient of drag with different angle of attack is as shown in Figure. The major enhance in coefficient of lift for the 3% height Gurney flap comes at the charge of significantly improved drag as shown in fig. It has been revealed that both the coefficients of lift and drag for airfoil are improved with an increase in the Gurney flap height. The coefficient of drag for airfoil will suddenly raise when the height of Gurney flap exceeds 2%C. Based on these computed results, it can be suggested that the size of the optimum Gurney flap for better lift to drag ratio is decided by the flow stream parameters at the trailing edge on the pressure region of aerofoil.

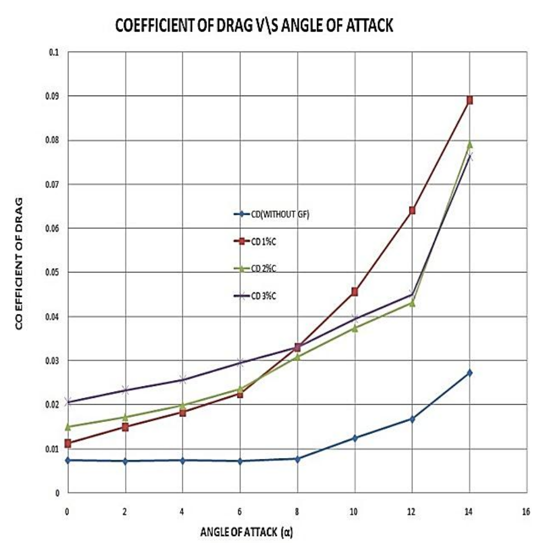


*Fig6. Drag coefficient verses Angle of attack*

***Static Pressure distribution on aerofoil***

The static pressure distribution in terms of non dimensional coefficient is as shown in Figure. The Coefficient of pressure distribution on aerofoil surface obtained for 3%C Gurney flap height with angle of attack and it is computed by graph as shown in fig. The pressure distribution on aerofoil for both without Gurney flap and with Gurney flap (3%C) is compared and obtained satisfied results near Gurney flap. The suction rate increase on suction surface of aerofoil which in turn increases pressure on aerofoil surface is clearly shown on location of Gurney flap. On pressure side of aerofoil, the coefficient of pressure increases for the airfoil with Gurney flap, while, on the suction side, the coefficient of pressure reduces. This results in enhancement of lift coefficient. Adverse pressure gradient exist on the pressure surface close to the trailing edge of the airfoil with Gurney flap. This leads to formation of recirculating vortex that appears close upstream of Gurney flap location.

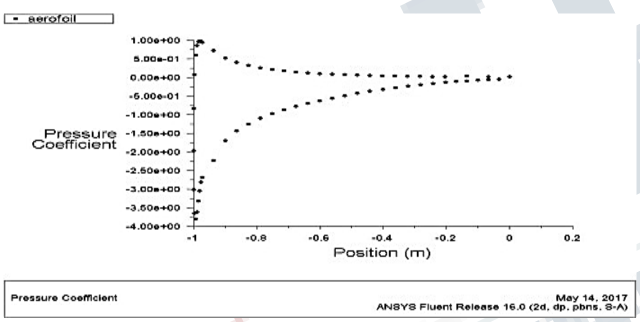



***Fig7.coefficient of pressure on aerofoil without GF for AOA 10$^0$***

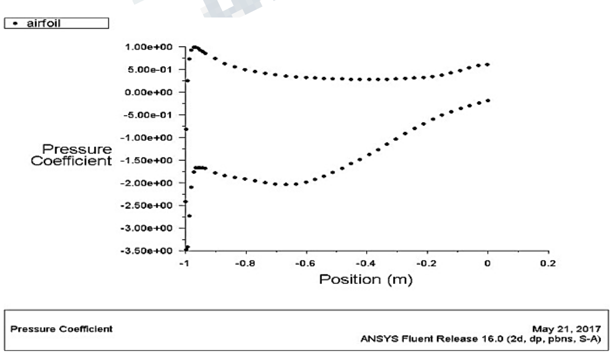



***Fig8.coefficient of pressure on aerofoil with GF (3%c) for AOA 10$^0$***

***Streamlines and Turbulence Intensity***

The stream of flow around the trailing edge of aerofoil with and without Gurney flap at an angle of attack is compared with the aid of streamlines and turbulence intensity as shown in figure. Two counter rotating vertices with high turbulent intensity are observable in the wake of the Gurney flap. In count to vortices in the wake, one extra vortex region is formed in front of the flap. These recirculation vertices are accountable for the improved suction on suction surface and improved pressure on the pressure surface which is leads to enhancement of lifting potential of the Gurney flap. As the height of Gurney flap increases, the force of the vortex form increases which leads to more deflection of the flow stream at the trailing edge around the flap location and enhances the effective downwash performance of aerofoil.

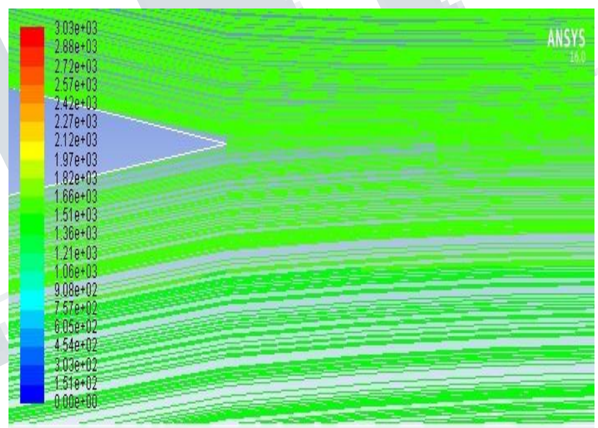
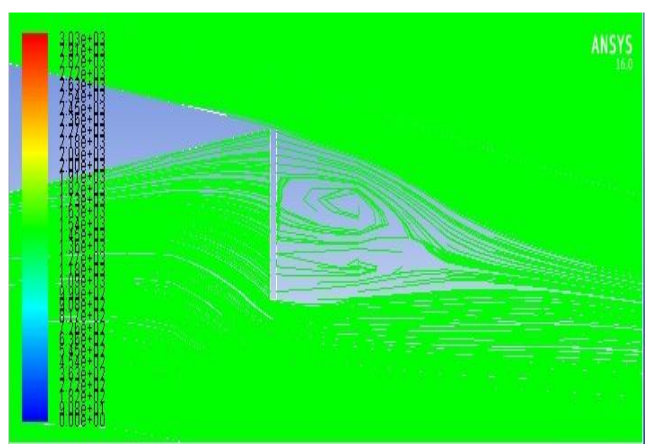



***Fig9. Streamlines for Aerofoil without Gurney flap***



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Vol 2, Issue 5, May 2017

*Fig Streamlines for Aerofoil Gurney flap of height 3%C*

## V. CONCLUSION

A computational approach carried out on the effects of Gurney flap on the aerodynamics performance of NACA0012 aerofoil without and with Gurney flap of height of 1 to 3% aerofoil chord has been studied. Ansys Fluent commercial CFD code with one-equation Spalart-Allmaras turbulence model is used for analysis at various angles of attack up to from these computed results, the following major conclusions are drawn. Computational results obtained in this study are satisfied practically well with existed experimental data.

A considerable increment in coefficient of lift is obtained with in slight charge in drag. The maximum coefficient of lift compared with the aerofoil without GF increased by 34%, 54% and 62% using the 1%, 2%, and 3% chord height Gurney flaps respectively.

Results describes that Gurney flaps provides a positive increase in coefficient of lift, a negative shift in the lift at zero angle of attack and a drag enhancement compared with those obtained for clean aerofoil, anyway these increments are nonlinear in comparison to height of flap. There is no considerable enhance in drag if height of Gurney flap is kept within boundary layer, anyhow beyond this limit drag growth i The pressure distribution over aerofoil surface, results prove that the Gurney flap increases the upper surface suction and the lower surface high pressure; this is the motivation why the lift can be improved.

The wake velocity profile with flow stream at the locality of the trailing edge shows that the presence of the Gurney flap causes in a downward turning of the flow field in the rear end of aerofoil, so that the Gurney flap increases the effective camber of the aerofoil. This study further shows that aerofoil designed with Gurney flap used to effectively improve the aerodynamic performance i.e., increasing coefficient of lift as well as the lift to drag ratio. The larger the height of GF, more the lift increment will be considerable.

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