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Modification of Airfoils Using Gurney Flaps: A Review

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Abstract

Overall performance of an aircraft depends on its lift to drag ratio. Better lift to drag ratio results in better performance of an aircraft. Better lift to drag ratio is also necessary to reduce the operating cost. The fuel consumption can be reduced by improving lift to drag ratio. In order to improve this lift to drag ratio researchers try to modify the basic unit of an airplanes wing for many years. The basic unit of an airplanes wing is termed as airfoil. It is the cross section of airplanes wing. Different types of modification on airfoil are performed in order to increase its performance. Some of the examples of airfoils surface modification are vortex generators, multiple winglets, flaps, dimples etc. In this present article a special type of modification named as Gurney flap which is attached to the airfoils trailing edge to improve the overall performance will be discussed. Different experimentations both experimental and numerical have been performed by several researchers around the world to identify the effect of Gurney flaps. In this present study an attempt is taken to sum up all of those experimentations.

Keywords

Aircraft, Airfoil, Drag, Gurney Flap, Lift.

1. Introduction

The cross section of an airplanes wing taken with the help of a plane perpendicular to the airplanes wing is termed as airfoil. Airfoil design is a critical issue for airplanes performance. A lot of airfoils have already been designed by National Advisory Committee for Aeronautics in the last century. But still now continuous efforts are given by researchers to create a new airfoil which will give performance better than the previous one. Modifications are also performed to identify the suitable combination of airfoil itself and the modifications performed. Gurney flap can be a good choice of modification due to its simplicity. Its design and construction is very easy and cost effective. Gurney flaps can be designed and constructed at a low cost. Gurney flaps are more economical than other modifications. Gurney flaps have its own history which will be discussed in the next sections of this article.

2. Concepts of Gurney Flap

Cross section taken by a plane which is perpendicular to the wing is termed as airfoil. Airfoil can be modified by using flaps.

Fig 2.1.A typical airfoil

Flaps are used to generate more lift at slower speed of aircrafts. Flaps make it possible for an airplane to fly at a reduced speed with minimum risk of possible problems. It is very essential for safe takeoff and landing.

Gurney flaps are special type of flaps which are designed by Dan Gurney. Gurney flap (GF) is a microtab fitted to the airfoil on its pressure side near the trailing edge .At first he used it on his racing car to achieve minimum drag force. Below simple photograph of a typical flapped airfoil and a typical airfoil with Gurney flap are given. The difference between normal flaps and Gurney flaps can easily understand if these two photographs are compared.

Fig2.2.A typical Airplane Wing with Flap

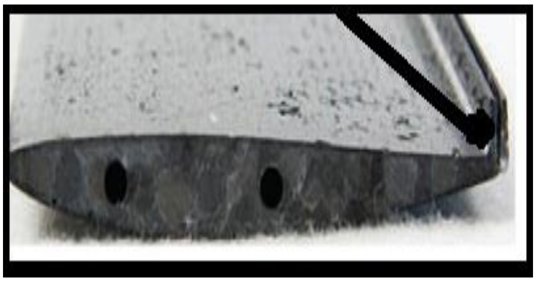

Fig2.3.A typical Airfoil with Gurney Flap

3. Investigations Performed with Airfoils Modified by Using Gurney Flaps

R Myose et al. (1996) investigate the consequences of Gurney flaps on a NACA 0011 airfoil. They found Gurney flaps offer a considerable boost in lift while there was a small reduction in drag. NACA 0011 airfoil with Gurney flaps produces more coefficients of lift which is better than regular NACA 0011 airfoil [1].

David Jeffrey et al. (2000) investigate the aerodynamics of Gurney flaps. They experimented with a model which was fitted with gurney flaps on the trailing-edge region. They measured surface pressure distribution, force, and speed by using laser doppler anemometry (LDA). They found that using gurney flaps near trailing edge results in an increase of circulation [2].

Neung-Soo Yoo (2000) numerically investigates the performance of NACA23012 airfoil fitted with Gurney flaps. Flow field was determined by using Navier-Stokes code and RAMPANT. His investigations demonstrate that the Gurney flap amplified both coefficient of lift and drag. His results also showed flow structures at the trailing edge [3].

J. Nožicka et al. (2006) write down a review article where they sum up the characteristics of NACA 23012 and FX66-17AII-182 airfoil using gurney flaps. They sum up the performances of NACA 23012 and FX66-17AII-182 airfoil for various angles of attack. Characteristics were evaluated with the help of 2D-PIV (Two-dimensional Particle Image Velocimetry) system [4].

Stefan Vey et al. (2008) perform experimental analysis to investigate the vortex characteristics at flap edge. They have experimented using different heights of flaps. Gurney flaps formed considerable distinction of the vortex centroids [5].

P. F. Zhang et al. (2009) investigate the consequence of a novel plasma Gurney flap on the aerodynamic characteristics of a NACA 0012 airfoil. Navier–Stokes equations were used for performing mathematical calculations. Simulations were performed using designed models. The outcomes show that the plasma Gurney flap results in an increase of lift of the airfoil. They boost the lift-to-drag ratio before stall [6].

T. Lee and Y. Y. Su (2010) study the effects of Gurney flaps having dissimilar heights and perforations. They used NACA 0015 airfoil to determine the aerodynamic characteristics. They also investigate the wake formation. At a Reynolds number of 2.54×10^5 investigations were performed. Addition of the Gurney flap results in a considerable boost in the lift and drag. The height of the Gurney flap influences the aerodynamic characteristics very much but perforation had only a little effect on the wake formation and aerodynamic characteristics [7].

Md. Arfan Uddin and A.B.M. Toufique Hasan (2011) perform a CFD analysis using NACA0012 airfoil. They try to observe the effects of geometry of flaps on aerodynamics of their designed model. They choose Gurney flaps to modify NACA0012 models. Computational outcomes were compared with the existing experimental data in order to validate their CFD study. They choose both rectangular and triangular gurney flaps for their study. Both of them show enhancement of lift to drag ratio [8].

Masoud Jahanmorad Nouri et al. (2012) perform numerical investigations using NACA 23018 airfoil. In order to look upon the consequences of a Gurney flap on the NACA 23018 airfoil a two-dimensional numerical analysis was performed. Evaluated outcomes were weighed against existing experimental data. The results are in agreement that Gurney flap escalates the lift coefficient. The results also agree that there is an increase in aerodynamic performance when Gurney flaps are used [9].

Shubham Jain et al. (2015) perform a CFD study using NACA 0012 airfoil fitted with Gurney flaps to investigate change in aerodynamic characteristics at different Reynolds number. Both coefficients of lift and drag increase when fitted with Gurney flap while weigh against those without Gurney flap at different Reynolds numbers. This is accurate for the entire perspective of attack. Angle of stall reduced by 2 degree in case of airfoil fitted with Gurney flap. However lift coefficient declines very quickly at Reynolds number which is below critical range [10].

Manish K. Singh et al. (2015) investigate using NACA 4412 and NACA 0011 airfoils modified with

Gurney flaps. They perform a steady state Navier-Stokes computation in two dimensions using these two models. The size of the Gurney flap varies minimum 0.5% to maximum 4% of the chord length. Comparisons have been performed between obtained results by computational method and available experimental data. Modification of airfoils with Gurney flap boosts the coefficient of lift extensively with too small drag if appropriate Gurney flap altitude is chosen [11].

Li-Hao Feng et al. (2015) perform an experiment to control the flow over an airfoil using virtual Gurney flaps. They choose NACA 0012 airfoil for their experiment. Studies were conducted using dielectric barrier discharge (DBD) plasma actuator. The study was performed using a Reynolds number of 20000. The virtual Gurney flap modifies the dynamics of laminar separation bubbles. Modification of flow surrounding the airfoil results in an increase in the coefficient of lift. The intention of this exploration is to realize the mechanism of lift production by virtual Gurney flaps [12].

Shubham Jain et al. (2015) perform a computational analysis using NACA0012 airfoil. They fitted Gurney flap on their airfoil model. They used FLUENT for their computational study. The height of the Gurney flaps varies from 0.5% to 4% of the chord length. Analysis was performed for seven individual positions varied from minimum 0%to maximum 20% of the chord length. The outcomes were in agreement that Gurney flaps having a height of 1.5% of chord length at a distance which is near to the trailing edge results in maximum lift improvement with smallest drag punishment [13].

Ho Chun Raybin Yu (2015) investigates the combination of shockbump and Gurney flap on a supercritical airfoil and a laminar flow airfoil. The supercritical airfoil chosen for the investigation was RAE2822 and the natural laminar flow airfoil chosen was RAE5243. The height of the Gurney flap had a range from minimum 0.1% to maximum 0.7% of the chord length. Outcomes specify that Gurney flaps have the capacity to transfer shock downstream for both types of airfoil tested. A considerable increase in lift-to-drag ratio is found in case of RAE2822 airfoil. But no improvement is observed in case of RAE5243 airfoil. Outcomes indicate that Gurney flap can reduce the drag [14].

A Mahboubi Doust (2015) performs CFD study across a NACA0012 plunging airfoil. NACA0012 airfoil was equipped with dissimilar Gurney flaps having heights of minimum 2% of chord length and maximum 7% of chord length. The analysis was carried out with a Reynolds number of 1850. For flow management across the airfoil, dielectric-barrier discharge plasma actuator is fitted to the flap. For the above mentioned model of airfoil it is found that Gurney flap having height equal to 2% of total chord length results in more boosts in coefficient of lift [15].

Valentina Motta et al. (2016) numerically investigate the effects of L-shaped Gurney flap. They performed a CFD investigation to explore the consequence of Gurney flap on airfoil. Simulations were performed using NACA 0012 airfoil outfitted with L-shaped Gurney flaps. The investigations were performed for numerous angles of attack for both in linear and stall regimes. The CFD results were validated by comparing the simulation outcomes with experimental data and PIV surveys [16].

V. Motta and G. Quaranta (2016) illustrate the capacity of Gurney flap which is L-shaped fitted near trailing-edge as a contrivance for reduction of vibration. The outcomes in agreement that L-shaped Gurney flaps are reasonable for vibration reduction of rotor blades [17].

L. Brown and A. Filippone (2016) evaluate the study on Gurney flaps and interconnected high lift trailing edge plans. They examined at Reynolds numbers which is equal or less than 10^5.Optimization of device heights for every case have been performed. A semi-empirical principle connected to the height of Gurney flap is anticipated. This empirical formula correlates stream velocity and chord length of airfoil. The outcomes suggest that the optimum size of the devices should always less than boundary-layer thickness near trailing edge [18].

Manjunatha Patil et al. (2017) perform their study using NACA0012 airfoil in order to understand the effect of Gurney flap. They perform CFD analysis using the models of NACA0012 airfoil fitted with Gurney flaps. Height of Gurney flap is taken in a range of 1 to 2% of the chord length. They show the details of flow nature at the trailing edge. They also show the information's related to airfoil performance [19].

Muralikrishnan Gopalakrishnan Meena and Kunihiko Taira (2017) numerically investigate the exploit of Gurney flap. They perform their study using NACA 0000, NACA 0006, NACA0012 and NACA0018 airfoils. 1000 is taken as Reynolds number. They identified that the addition of Gurney flap at the trailing edge make it possible for the airfoil to generate more lift force. They also observed reduction in drag force. Lift-to-drag ratio is also increased .As the lift to drag ratio increases the performance also increases. [20].

4. Wind Tunnel Investigations of Airfoils Modified by Gurney Flaps

Y.C. Li et al. (2007) perform experiments using Wind tunnel to explore the possessions of divergent trailing edges and Gurney flaps on a supercritical airfoil. They performed experiment at a Mach number M=0.7 and a Reynolds number $Re=3.15\times10^5$. Their experimental outcomes exposed that the Gurney flaps had considerable effects on improving the aerodynamic characteristics of the airfoil when compared with the airfoils having divergent trailing edges [21].

Hao Li-shu et al. (2013) perform investigation using Gurney flap and vortex generators. They compare the effects of Gurney flap and vortex generators. They perform individual investigations of regular airfoil, airfoil with Gurney flap, airfoil with vortex generators and airfoil having both Gurney flap and vortex generators. Experimentation using wind tunnel showed that for same angle of attack Gurney flap model have more lift then the other models. Angle of stall is significantly increased by using vortex generators. But these two parameters have their best values when Gurney flap and vortex generators combined together. The results concluded that with proper combination of Gurney flap and vortex generators extraordinary improve the aerodynamic characteristics of an airfoil [22].

Michael A. Cavanaugh et al. perform wind tunnel testing using a model of NACA23012 airfoil having an aspect ratio of 6 outfitted with Gurney flaps and T-strips situated at trailing edge. The experimentation was performed at the University of Washington using a wind tunnel having eight by twelve foot cross section area at three individual Reynolds numbers. The Reynolds numbers were 1.95×10^6, 1.02×10^6 and 0.51×10^6. Prepared NACA 23012 airfoil models have a span of 90 inch with a chord length of 15 inches constantly distributed. The height of the Gurney flaps were determined minimum 0.21% and maximum 5.00% of the chord length. Outcomes of that experiment were in agreement that Gurney flaps results in an affirmative increase in coefficient of lift [23].

5. Conclusions

From the above mentioned review of the articles it can easily understand that Gurney flaps have a large scope for further study. They can increase coefficient of lift, reduce coefficient of drag and change angle of stall. Different types of Gurney flaps have different impact on the modified airfoils. Modification of airfoils using Gurney flaps can result in a high lift to drag ratio which in turn reduces the operating costs of airplanes. Both computational and experimental study using Gurney flaps on airfoil models is possible. Investigations or modification of airfoils with Gurney flaps can be a good choice for the young researchers.

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