DESIGN AND ANALYSIS OF PERFORMANCE PARAMETERS OF WING WITH FLAPERONS

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***ABSTRACT*- The main objective of this project is to design a flaperon for a wing and compare the performance characteristic of this flaperon-wing combination with that of conventional wing design that makes use of separate flap and aileron. Theoretical analysis and comparison is performed following which the computational analysis is carried out to validate the results. Further aim is to give a clarity on the fact that the use of this high lift device aids in improvising the aerodynamic characteristics of a wing by experimental testing of the wing design incorporated with flaperon, which is designed using a special methodology. Then, modification of wing design can be done to overcome the drawbacks of flaperons if any.**

INTRODUCTION -

When looking at an aircraft, it is easy to observe that they have a number of common features: wings, a tail with vertical and horizontal wing sections, engines to propel them through the air, and a fuselage to carry passengers or cargo. If, however, you take a more critical look beyond the gross features, you also can see subtle, and sometimes not so subtle, differences. The reasons for these differences, why the designers configured them this way, is quite an intriguing study.

Today, 100,000 flights will safely crisscross the planet. At no time in history have our lives been so global and full of possibility. Even if you have never boarded a plane, aviation brings the world to you. Ten million people board a plane everyday – for trade, for tourism, or to connect with loved ones. Another ten million people earn their livelihood by making this possible. This method of connecting to any part of the world has made lives easier and simpler. It has indeed made the world look small. Airplane design is both an art and a science. In that respect it is difficult to learn by reading a book; rather, it must be experienced and practiced. However, we can offer the following definition and then attempt to explain it. Airplane design is the intellectual engineering process of creating on paper (or on a computer screen) a flying machine to (1) meet certain specifications and requirements established by potential users (or as perceived by the manufacturer) and/or (2) pioneer innovative, new ideas and technology. The design of airplane involves the design of fine components to the large external structures that completes the design process. The design process is indeed an intellectual activity, but a rather special one that is tempered by good intuition developed via experience, by attention paid to successful airplane designs that have been used in the past, and by (generally proprietary) design procedures and databases (handbooks, etc.,) that are a part of every airplane manufacturer. The design of an aircraft draws on a number of basic areas of aerospace engineering including aerodynamics, propulsion, light-weight structures and control. Each of these areas involves parameters that govern the size, shape, weight and performance of an aircraft. Although we generally try to seek optimum in all these aspects, with an aircraft, this is practically impossible to achieve, because optimizing one characteristic degrades another. Apart from design the fabrication of each and every component of the aircraft plays a key role in the efficient flight of the aircraft. Considerations about the possible failure modes must be considered to carry out an effective fabrication process. The fabrication of parts is done on an individual basis and similarly the external structure of an aircraft is also manufactured in several pieces and then they are assembled. An aircrafts' safe flight depends on how effective and efficient is its control surface design. The control surfaces have a tremendous impact on the flight efficiency. Control surface design is of primary importance in aircraft design process. Without proper control surfaces the flight of an aircraft is itself a question mark. This project work focuses on the design modification of conventional control surfaces by combination of two control surfaces and thereby helping in effective improvement of the aerodynamic performances of an aircraft. In the present era where aviation industry is advancing beyond the imagination, weight reduction is still a major challenge in this field. Blended wing concept is one such attempt for weight reduction, due to the complications in this idea control surfaces are combined for weight reduction purpose and other advantages like better controllability, decreased take off and landing distance etc. Elevons flaperons are examples of combined control surfaces.

DESIGN OVERVIEW:

FLIGHT CONTROL SYSTEM:

Aircraft flight control systems consist of primary and secondary flight control systems. The ailerons, elevators (or stabilators), and the rudder constitute the primary control system and are required to control an aircraft safely during flight. Wing flaps, leading edge devices, spoilers and trim system constitute the secondary control system and improve the performance characteristics of the airplane or relieve the pilot of excessive control forces.

PRIMARY FLIGHT CONTROLS:

AILERONS:

Ailerons control roll about the longitudinal axis. The ailerons are attached to the outboard trailing edge of each wing and move in the opposite direction from each other. Ailerons are connected by cables, bell cranks, pulleys, and/or push-pull tubes to a control wheel or control stick. Moving the control wheel, or control stick, to the right causes the right aileron to deflect upward and the left aileron to deflect downward. The upward deflection of the right aileron decreases the camber resulting in decreased lift on the right wing. The corresponding downward deflection of the left aileron increases the camber resulting in increased lift on the left wing. Thus, the increased lift on the left wing and the decreased lift on the right wing causes the aircraft to roll to the right.

ELEVATOR:

The elevator controls pitch about the lateral axis. Like the ailerons on small aircraft, the elevator is connected to the control column in the flight deck by a series of mechanical linkages. Aft movement of the control column deflects the trailing edge of the elevator surface up. This is usually referred to as the up-elevator position. The up-elevator position decreases the camber of the elevator and creates a downward aerodynamic force, which is greater than the normal tail-down force that exists in straight-and-level flight. The overall effect causes the tail of the aircraft to move down and the nose to pitch up. The pitching moment occurs about the center of gravity (CG). The strength of the pitching moment is determined by the distance between the CG and the horizontal tail surface, as well as by the aerodynamic effectiveness of the horizontal tail surface. Moving the control column forward has the opposite effect. In this case, elevator camber increases, creating more lift (less tail-down force) on the horizontal stabilizer/elevator. This moves the tail upward and pitches the nose down. Again, the pitching moment occurs about the CG.

RUDDER:

The rudder controls movement of the aircraft about its vertical axis. This motion is called yaw. Like the other primary control surfaces, the rudder is a movable surface hinged to a fixed surface in this case, to the vertical stabilizer or fin. The rudder is controlled by the left and right rudder pedals. When the rudder is deflected into the airflow, a horizontal force is exerted in the opposite direction. By pushing the left pedal, the rudder moves left. This alters the airflow around the vertical stabilizer/rudder and creates a sideward lift that moves the tail to the right and yaws the nose of the airplane to the left. Rudder effectiveness increases with speed; therefore, large deflections at low speeds and small deflections at high speeds may be required to provide the desired reaction. In propeller-driven aircraft, any slipstream flowing over the rudder increases its effectiveness.

SECONDARY FLIGHT CONTROLS:

FLAPS:

Flaps are the most common high-lift devices used on aircraft. These surfaces, which are attached to the trailing edge of the wing, increase both lift and induced drag for any given AOA. Flaps allow a compromise between high cruising speed and low landing speed because they may be extended when needed and retracted into the wing's structure when not needed. There are four common types of flaps: plain, split, slotted, and Fowler flaps. The plain flap is the simplest of the four types. It increases the airfoil camber, resulting in a significant increase in the coefficient of lift (CL) at a given AOA. At the same time, it greatly increases drag and moves the center of pressure (CP) aft on the airfoil, resulting in a nose-down pitching moment. The split flap is deflected from the lower surface of the airfoil and produces a slightly greater increase in lift than the plain flap. More drag is created because of the turbulent air pattern produced behind the airfoil. When fully extended, both plain and split flaps produce high drag with little additional lift. The most popular flap on aircraft today is the slotted flap. Variations of this design are used for small aircraft, as well as for large ones. Slotted flaps increase the lift coefficient significantly more than plain or split flaps.

SPOILERS:

Found on some fixed-wing aircraft, high drag devices called spoilers are deployed from the wings to spoil the smooth airflow, reducing lift and increasing drag. On gliders, spoilers are most often used to control rate of descent for accurate landings. On other aircraft, spoilers are often used for roll control, an advantage of which is the elimination of adverse yaw. To turn right, for example, the spoiler on the right wing is raised, destroying some of the lift and creating more drag on the right. The right wing drops, and the aircraft banks and yaws to the right. Deploying spoilers on both wings at the same time allows the aircraft to descend without gaining speed. Spoilers are also deployed to help reduce ground roll after landing. By destroying lift, they transfer weight to the wheels, improving braking effectiveness

TRIM TABS:

The most common installation on small aircraft is a single trim tab attached to the trailing edge of the elevator. Most trim tabs are manually operated by a small, vertically mounted control wheel. However, a trim crank may be found in some aircraft. The flight deck control includes a trim tab position indicator. Placing the trim control in the full nose-down position moves the trim tab to its full up position. With the trim tab up and into the airstream, the airflow over the horizontal tail surface tends to force the trailing edge of the elevator down. This causes the tail of the aircraft to move up and the nose to move down. If the trim tab is set to the full nose-up position, the tab moves to its full down position. In this case, the air flowing under the horizontal tail surface hits the tab and forces the trailing edge of the elevator up, reducing the elevator's AOA. This causes the tail of the aircraft to move down and the nose to move up.

WING AND CONTROL SURFACE SIZING:

Due to of the importance of the roll control in a fighter aircraft, span of the flaps must be selected as short as possible, so that the span of the aileron is long enough. Therefore, in a fighter aircraft, it is advised to design the aileron prior to flap design.

AILERON SIZING:

Design parameters of Aileron

Area of aileron= 5 – 10 % of wing area

Span of aileron = 20-30% of wing span

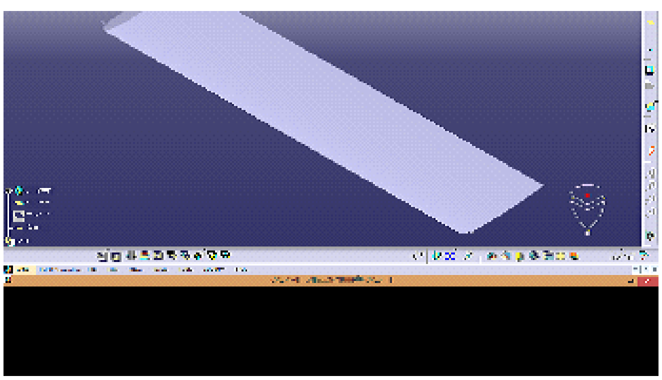
Chord of aileron=15-25% of wing chord

Inner edge of aileron= 60-70% of span

Deflection of aileron = ± 30 deg

Aileron chord = 20% of wing chord

Aileron area = 8% of wing area



FLAP SIZING:

The main factors needed for flap design are the-

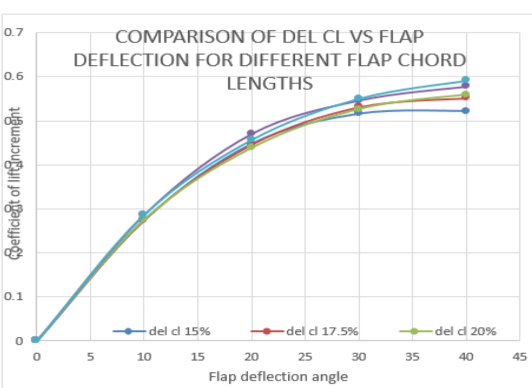
1. Type of flap
2. Maximum Flap deflection
3. Span of the flap

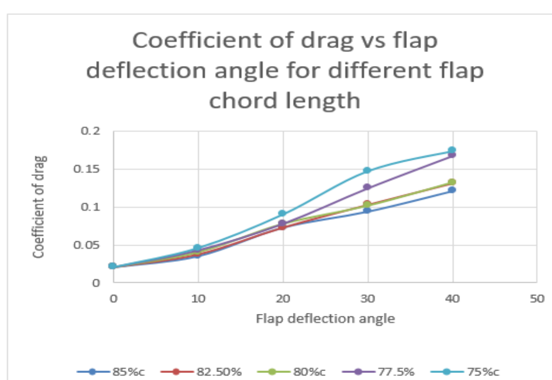
4. Flap chord

The flap used is the plain flap, thus the flap motion correction factor will be 1.The rear portion of airfoil rotates downwards on a simple hinge mounted at the front of the flap. Due to the greater efficiency of other flap types, the plain flap is normally only used where simplicity is required. The maximum deflection of the flap is considered around 40 degrees. It is necessary to fix the flap span and the flap chord. The flap span is fixed by taking into account of the aileron span which has been fixed by using the aileron sizing. The span of the aileron extends from the wing root to about 55% of the wing. The airfoil co-ordinates are imported from the airfoil tools available online and the co-ordinates are typed as such compatible with the Ansys design modeler. These co-ordinates are designed as such the trailing part of this airfoil is deflected at a definite Flap deflection angle and the analysis is done on the airfoil at different chord locations at a constant angle of attack. The Aileron is sized based on the historical perspective as well as the literature survey. Similarly the flap is also designed based on the aileron design. The flap chosen is the plain flap, because it satisfies the requirement of the additional lift. The deflection of flap produces additional lift which can be used during take-off. The Flap chord must be fixed only by comparing the increment in lift produced by the flaps by placing it in different chord locations at any fixed flap deflection and the angle of attack .The flap chord can vary between 15% to 25% of the wing chord extending in the trailing edge. When the flaps chord length is high it is found that the lift produced is high, comparatively the drag is also high. But when the flap's chord length is low, the lift produced as well as the drag is low. Thus we are taking a nominal value of flap chord. Computational analysis is done using the ansys workbench at a reference angle of attack of 11 degree and flap deflection angle of 40 degrees, the flap location along the chord is varied and the computational analysis is done to compare the coefficient of lift and coefficient of drag. The Flap chord chosen is the 20 % chord length.

Flap deflection	15% chord	17.5% chord	20% chord	22.5% chord	25% chord
0	0	0	0	0	0
10	0.2739	0.2748	0.2755	0.2862	0.2865
20	0.4471	0.4457	0.438	0.47	0.4563
30	0.5158	0.531	0.5264	0.5462	0.55
40	0.522	0.5516	0.5591	0.5779	0.591

Flap deflection	15% chord	17.5% chord	20% chord	22.5% chord	25% chord
0	0.02082	0.02082	0.02082	0.02082	0.02082
10	0.03542	0.03786	0.04072	0.04320	0.04617
20	0.07302	0.07328	0.07788	0.07816	0.09047
30	0.09411	0.10329	0.10181	0.12519	0.14756
40	0.12116	0.13177	0.13239	0.16804	0.17402





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MORPHING:

Morphing is nothing but the smooth transformation of one image into another by computer, as in a motion picture. Optimization of morphing airfoils is performed separately to the morphing mechanism design. The FishBAC morphing system is chosen as the example mechanism, and it is shown that the FishBAC can achieve large improvements in performance over non morphing airfoils when multiple flight conditions are considered.

The linear regression morphing is defined by :

$M\ t = t \cdot P + t \cdot Pt \in (\ 1)$

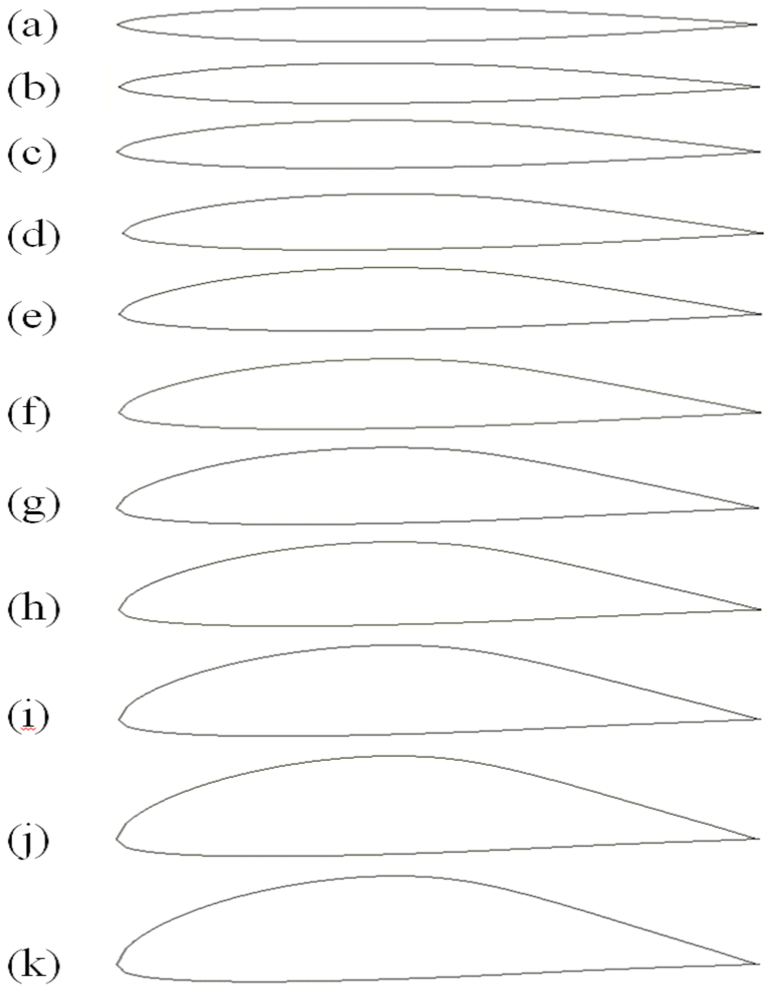
where t is the morphing parameter , M(t) is the generated model and P0 and P1 denote the parent models. The linear regression morphing is carried out on two airfoils taking the coordinates of both the airfoil as the morphing parameter, nearly 200 points were taken, morphed by using the formula given below

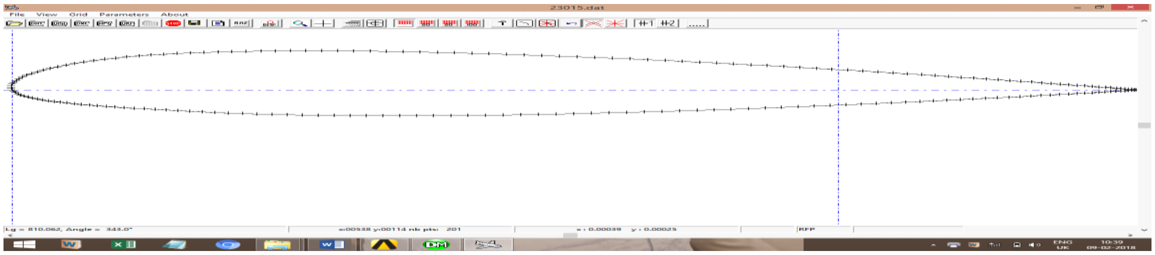
$M(x) = t\,[P1(x)] + (1-t)\,[P2(x)]$, t morphing parameter whose value varies from 0.1

to 0.9.

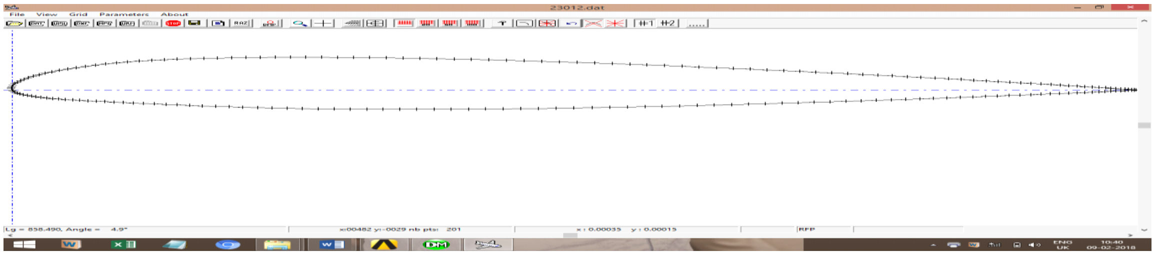
Parent models and newly generated model:

(a) the first parent model (t = 0); (b) t = 0.1; (c) t = 0.2; (d) t = 0.3; (e) t = 0.4; (f) t = 0.5; (g) t =0.6; (h) t = 0.7; (i) t = 0.8; (j) t = 0.9; (k) the second parent model (t = 1).

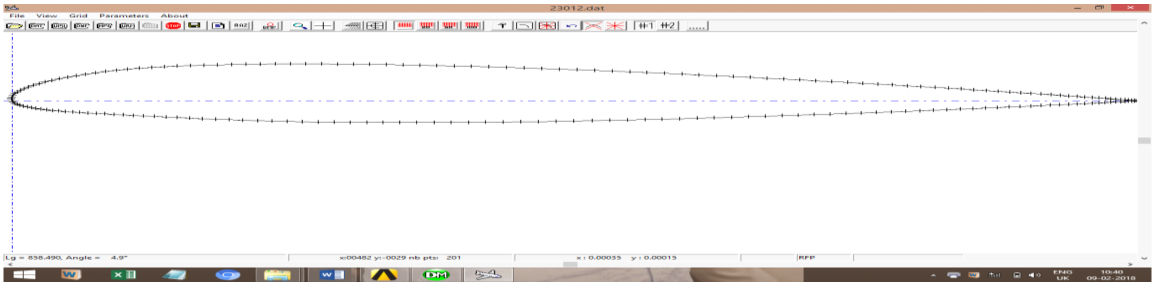




NACA 23015- PARENT 1



NACA 23012 - PARENT 2



OPTIMIZED AIRFOIL

Optimized airfoil from the parent airfoils for root and tip airfoils NACA 23015 and NACA 23012

By carrying out the computational analysis using ANSYS WORKBENCH, with and without flaps deflected and with flaperons deflected we observed increase in lift while employing flaperons.

ROLL RATE PERFORMANCE:

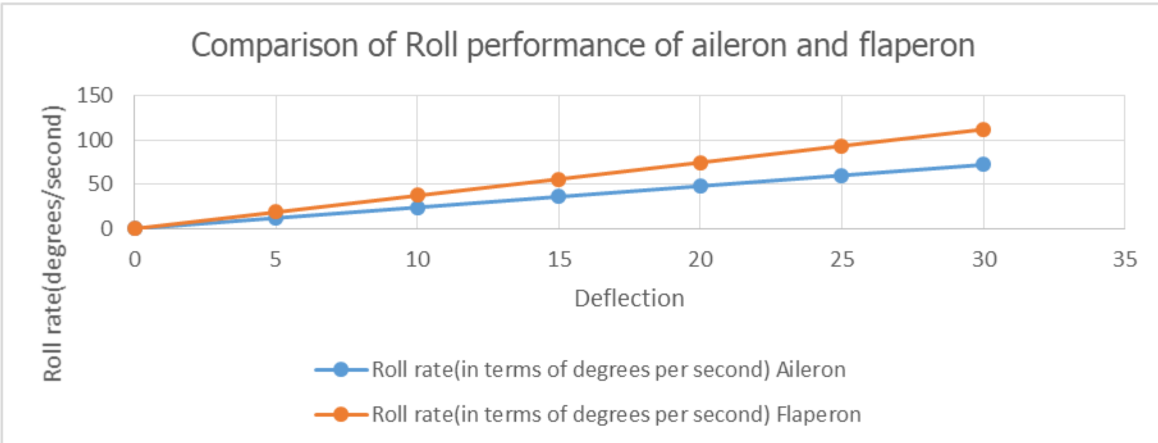
- Non dimensional rate can be calculated as

$$\frac{\mathrm{Pb}}{2\mathrm{V}} = \frac{\mathrm{C_L}\ \delta a}{\mathrm{C_{Lp}}}\delta a$$

- The roll rate of the aileron in the conventional wing is around 72 degrees/sec.
- For the wing which is designed with flaperons. The flaperons act both as flaps and ailerons so the span of the flaperon extends from the wing root till 95% of the wing span.
- The roll rate of the wings fitted with flaperons is around 112 degrees/second.
- The roll performance of both the wings fitted with the aileron as well as flaperon are compared by taking one of the parameter as the analysing parameter and the other parameter as the input parameter and then deriving a solution. In this comparative study, the aileron deflection is taken as the input parameter and the roll rate is taken as the analysing parameter and the comparison is made.

COMPARISON OF ROLL PERFORMANCE OF AILERON AND FLAPERON:

It has been observed that the roll rate is increased by 35% by employing flaperon for roll control instead of using the previously used aileron



COMPARATIVE STUDY:

WINGS	LIFT FORCE	DRAG FORCE
WINGS WITH UNDEFLECTED FLAPS	2462.5030 N	284.1202 N
WINGS WITH DEFLECTED FLAPS	3607.381 N	385.886 N
WINGS WITH DEFLECTED FLAPERONS	5067.264 N	388.528 N

δa(rad)	Roll rate(in terms of degrees per second)	
	Aileron	Flaperon
0	0	0
5	12.06147234	18.71882198
10	24.12294468	37.43764396
15	36.18441703	56.15646593

20	**48.24588937**	**74.87528791**
25	**60.30736171**	**93.59410989**
30	**72.36883405**	**112.3129319**

CONCLUSION:

From the above comparison, we could infer that without any flaps deflected the lift force produced is around 2460 N and when the flaps are deflected the lift produced 3607 N which can be used for the take-off. If we use the flaperons instead of the flaps, the compression produced at the lower part causes lift augmentation which is around 5067N. Thus the lift produced increases as we increase the span length of the flaps combining the flaps and aierons. In addition to increase in lift, the roll rate achieved increases by 35%.

FUTURE WORKS:

- FishBAC Theory
- Fabrication of wings with Flaperons
- Methodologies to reduce the weight of operating system

REFERENCES:

- Michael todorov (2005). Aerodynamic Characteristics of Airfoil with Single Plain Flap for Light Airplane, *Institute of Electrical and Electronics Engineers.*
- Eggleston,B, McKinney, W.D, Banaszek,J, Choi,N.S, Krolikowski,G, Lebrun,F, Thompson.J, Zingg,D.W, Nemec.M, and De Rang,S. (2002). Developing a New Flap for a Light Utility Transport Aircraft, *International Council of the Aeronautical Sciences.*
- Md Akhtar Khan, Karrothu Vigneshwara, Suresh Kukuta, and Avinash Gupt(2014). Effect of spikes integrated to airfoil at supersonic speed, *International Journal of Research in Engineering and Technology.*
- Subbarao.P.M.V, *Theoretical & Industrial Design of Aerofoils,* India: Indian Institute of Technology.
- Tulapurkara,E.G., *Wing design - selection of wing parameters,* India: National Programme on Technology Enhanced Learning.
- Noel Becar, *Selecting a suitable wing section,* California.
- Perkins C.D. and Hage R.E. (1988). *Airplane performance stability and control*. New York: John Wiley & Son.Inc.
- John D. Anderson (2002). *Fundamentals of aerodynamics* .New York: Mcgraw-Hill international editions.