International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 6, ISSN No. 2455-2143, Pages 13-16
Published Online April - May 2016 in IJEAST (http://www.ijeast.com)

ANALYSIS ON NACA 2412 AIRFOIL FOR UAV BASED ON HIGH-LIFT DEVICES

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***Abstract*— The main objective of this paper is to design a wing [based on NACA 2412 airfoil] for UAV based on different high lift devices. Firstly, this paper shows the modeling of wing alone and after that with plain flap, split flap, single-slotted flap and double slotted flap by using CATIA V5 and the simulation is done by ANSYS 15.0 with validating the design. [1]**

Obviously, this paper aim is to get maximum lift to achieve high endurance factor values and short take-off and landing distances.

This paper addresses the use of flaps for getting high lift and also the merit and de-merit of adding flaps on plain wing.

This paper not only addresses aerofoils design, but also the 3-D wing design with flap for low Reynolds number.

Keywords— **CATIA V5, ANSYS 15.0, CFX Solver, UAV, Aerodynamics, plain flap, split flap, single slotted flap and double slotted flap.**

I. INTRODUCTION

In 1917, the first UAV was successfully developed. Now a days, UAV having three category: Conventional, Unconventional and with Rotor.

UAV is used to monitoring and surveillance at the time of Election, Riots also it helps to supervise forest and country boundaries.

As UAV is small design air vehicle and because of that it have some drawbacks like poor flying, short endurance, fast landing causes equipment damage and etc.

To overcome these drawbacks, this paper is one more step to analyze wings [NACA 2412 Aerofoil, NACA 2412 airfoil has a maximum camber of 2% of the chord, located at 0.4c from the leading edge. The maximum thickness is 12% of the chord] with flaps at different angle of attack at low Reynolds number to get more Lift.

Flaps are high lift devices attached to the leading/trailing edge of a wing. It help to increase the value of C_L and the stall angle during the take-off phase of an aircraft. If the stalling angle is higher than to plain wing it allows the aircraft to take-off at lower speeds and hence it can even take-off from shorter runways.

Obviously UAV have some drawbacks like short endurance, poor flying qualities, fast landings causes damage of equipment, low lift/drag ratio of flight.

High lift devices used for bearing surfaces are designed to expand the flight envelope by changing the local geometry according to phases of flight of the aircraft. This paper shows the result on NACA 2412.

While addressing, this paper some help has been taken from journals, highly motivated books, etc, which is mentioned in last.

II. CONFIGURATIONAL STUDY

CONFIGURATIONAL STUDY

In this chapter, geometrical details of the fixed wing UAV configuration and its variants are mentioned [1]:

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PARAMETERS	VALUE
Aspect Ratio	6
Span (m)	6
Chord (m)	1
Wing Area (m^2)	6
Flap Chord (m)	0.332
High Lift device Flap Span (m)	1.12

Simulation condition for this paper:

Simulation Conditions	
Parameters	**Value**
Reynolds Number	1.4 Million
Velocity (m/s)	20.42

Boundary Condition		
Parameters	**Condition**	**Value**
Domain	Farfield Flow	0.06 (Mach)
Wing	Wall	Adiabatic
Symmetry Wall	Symmetry	

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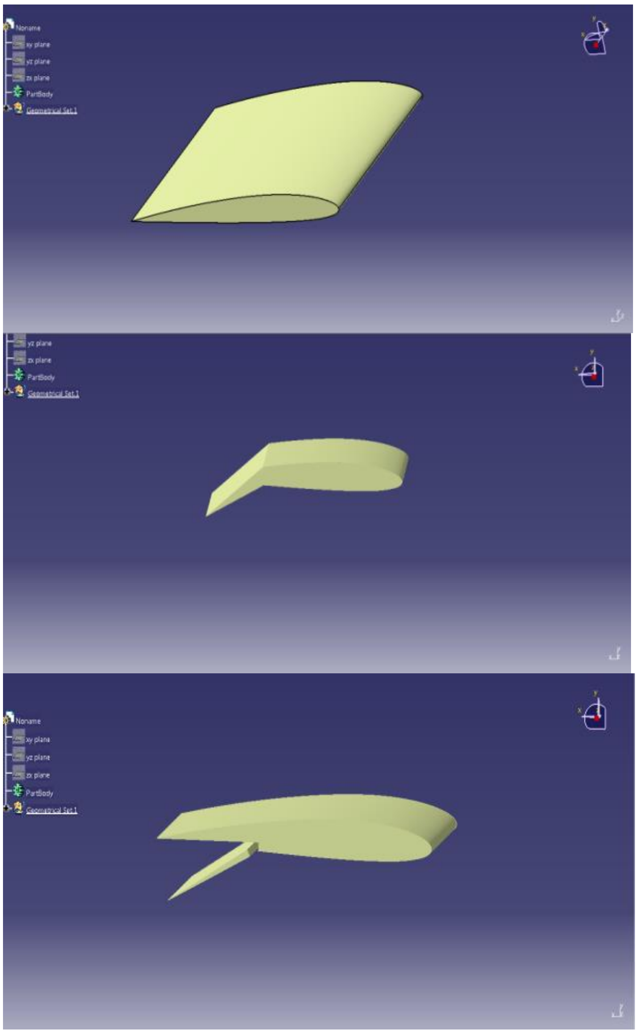
III. MODELLING AND SIMULATION

The methodology for computation involved the designing of NACA 2412 plain aerofoil, plain, split, single-slotted, double-slotted flaps on commercial CAD software CATIA V5.
The meshing of the designs for grid generation is done on ICEM CFD ANSYS 15.0 workbench. The CFD analysis was carried out using commercial code ANSYS FLUENT 15.0. The post processing of the results is done using ANSYS CFD POST.
The co-ordinates of NACA 2412 aerofoil were exported to part module of CATIA V5 which is software for modelling. The 2D aerofoil co-ordinates sketch was extruded using the pad command [10].
The NACA 2412 aerofoil with and without flaps are shown in Fig. 1.



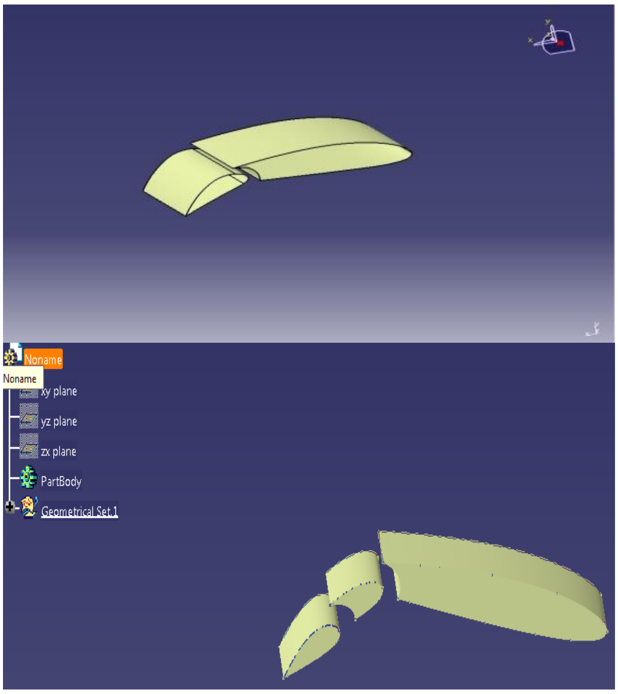


FIG.1. CATIA model of Plain wing, Plain flap, Split flap, Single Slotted flap and Double Slotted flap at fixed 10˚ angle of attack

IV. GRID AND SIMULATION

A bullet shaped fluid domain is created in part design module of CATIA V5and then import in ANSYS 15.0 software for the grid generation study. [1]

Tetrahedral surface meshing is done for generating the grid. Refinement was done on the leading edge of aerofoil, flaps. Coarse type sizing was used to generate the mesh.[1]

The mesh quality depends upon the value of smoothness which defines the rate of change of cell size (Fig.2).

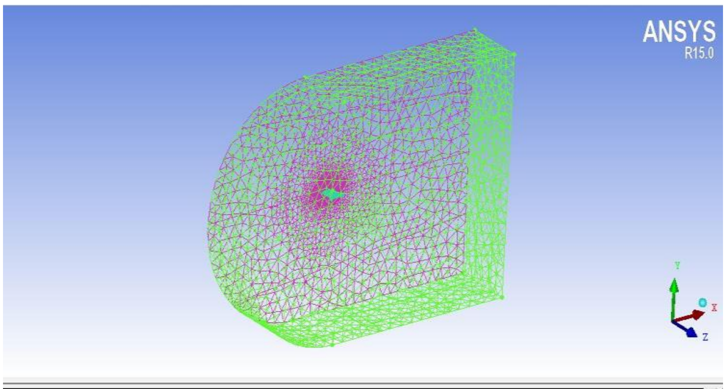


Fig.2. Surface meshing of the domain containing the plain wing with NACA 2412 aerofoil profile.

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V. LIFT-COEFFICIENT ANALYSIS

Fig. 3, Fig.4, Fig.5, Shows the Analysing of Lift Coefficient in between Plain wing, plain flap, split flap, single slotted flap and double slotted flap. The description of different AOA is below:

Angle of attack at 0°: At 1.4×10^6 Reynolds number, only plain flap and single slotted flap having maximum C_l (0.52) compare to others [see in Fig.3, 4, and 5], but out of these two single slotted having more C_d.

Fig.3. Results of CFX solver for the different types of flap of NACA 2412 aerofoil profile.

	PLAIN WING		PLAIN FLAP		SPLIT FLAP		SINGLE SLOT FLAP		DOUBLE SLOT FLAP	
AOA	Cl	Cd	Cl	Cd	Cl	Cd	Cl	Cd	Cl	Cd
0	0.055267	0.008662	0.519116	0.089915	0.33855	0.084821	0.523675	0.144396	0.30538	0.106631
2	0.106835	0.009767	0.558507	0.103999	0.363477	0.095312	0.537526	0.157881	0.352649	0.117597
4	0.157834	0.013217	0.592074	0.118133	0.403814	0.119494	0.582807	0.174989	0.393874	0.127765
6	0.208649	0.018343	0.619935	0.132197	0.463901	0.132492	0.625651	0.193027	0.43352	0.139858
8	0.259063	0.025261	0.647599	0.146892	0.488791	0.14692	0.665724	0.212478	0.47393	0.154244
10	0.308118	0.034375	0.670974	0.160939	0.528823	0.150097	0.698802	0.230474	0.508714	0.169737
12	0.363966	0.044691	0.5944	0.142477	0.571715	0.165717	0.746333	0.25003	0.543163	0.187647
14	0.396394	0.056393			0.659877	0.208694	0.802879	0.271204	0.572104	0.206135

Angle of attack at 4°: At 1.4×10^6 Reynolds number, Again only plain flap and single slotted flap having maximum C_l (0.58) compare to others [see in Fig.3, 4, and 5], but out of these two single slotted having more C_d.

Angle of attack at 8°: At 1.4×10^6 Reynolds number, Single slotted flap giving maximum C_l (0.67) compare to others [see in Fig.3, 4, and 5], but also having little more C_d compare to others..

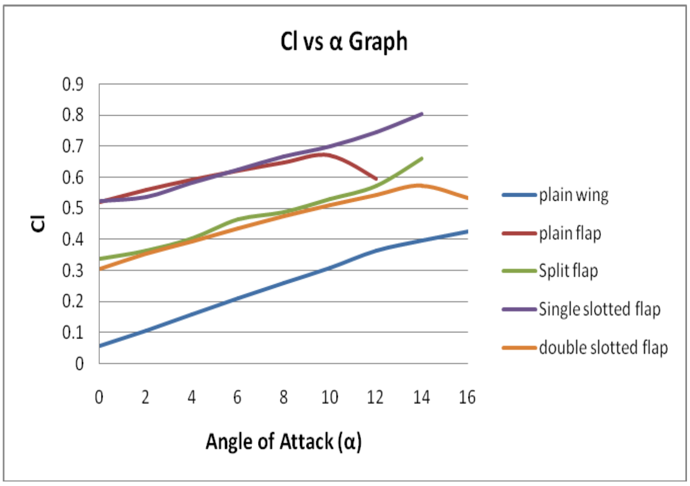

Fig.4. Cl vs α Graph of NACA 2412 Aerofoil with different types of flaps

Angle of attack at 12°: At 1.4×10^6 Reynolds number, Single slotted flap giving maximum C_l (0.75) compare to others [see in Fig.3, 4, and 5], but also having little more C_d compare to others.

VI. LIFT TO DRAG (L/D) RATIO ANALYSIS

Angle of attack at 0°: At 1.4×10^6 Reynolds number the value of L/D ratio for NACA 2412 wing with a single slotted flap at an angle 10° obtained is 3.626659 which is lower than the NACA 2412 wing with plain flap (5.77341).

Angle of attack at 4°: At 1.4×10^6 Reynolds number the value of L/D ratio for NACA 2412 wing with a single slotted flap at an angle 10° obtained is 3.3305 which is lower than the NACA 2412 wing with plain flap (5.011927).

Angle of attack at 8°: At 1.4×10^6 Reynolds number the value of L/D ratio for NACA 2412 wing with a single slotted flap at an angle 10° obtained is 3.13314 which is lower than the NACA 2412 wing with plain flap (4.408674).

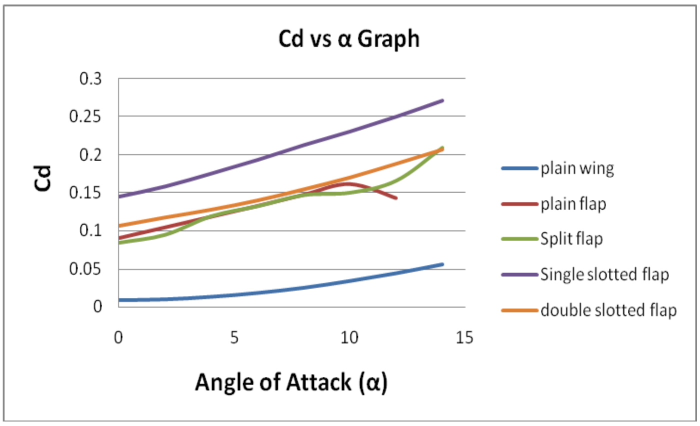

Fig.5. Cd vs α Graph of NACA 2412 Aerofoil with different types of flaps

Angle of attack at 12°: At 1.4×10^6 Reynolds number the value of L/D ratio for NACA 2412 wing with a single slotted flap at an angle 10° obtained is 2.98497 which is lower than the NACA 2412 wing with plain flap (4.171901).

VII. CONTOURS OF COEFFICIENT OF PRESSURE

The Coefficient of pressure (C_p) of a NACA 2412 wing with single slotted flap shown below:
The figure suggests that with increasing angle of attack from 0 to 12 degrees, the low pressure coefficient area tends to shift towards the leading edge on the upper surface. The magnitude of C_p of NACA 2412 wing with single slotted flap is lesser than the others. Thus, causing higher lift generation. [1]

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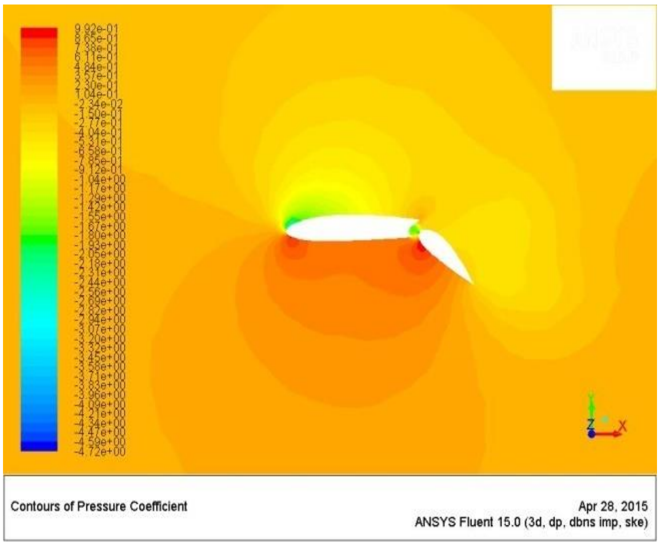

Fig.6. the coefficient of pressure contours on NACA 2412 wing with Single slotted flap at 10˚

VIII. VELOCITY STREAMLINES ANALYSIS

Velocity streamlines Analysis are used to study the path of a fluid as it moves over a structure or interacts with it.
Velocity line generated during post processing of CFD result, individually define the flow path of a fluid on the design.
In Figure 7, clearly shows that the turbulent flow gets shifted towards the trailing edge of the aerofoil and on the single slotted flap. Therefore, the flow over the upper surface of wing is almost laminar flow and gives higher C_l. [1]

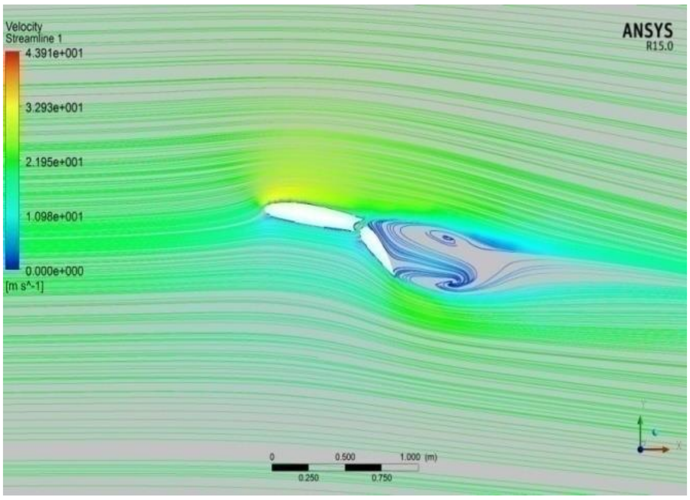

Fig.7. Streamline of velocity magnitude on NACA 2412 aerofoil with Single slotted Flap at 10˚, also showing turbulent flow at trailing edge.

IX. CONCLUSION & RESULT

The results obtained from the CFD analysis of single-slotted flaps fixed at 10 degree is the ideal for getting maximum lift coefficient ($C_{lmax.}$) and Lift to Drag ratio for UAV. [1]
Compare with fixed plain wing these values rectify the problem face at the time of take-off and landing time. [1]
With the modelling and analysis part completes, finally an optimum design of wing of UAV (with single-slotted flaps), which is giving more $C_{lmax.}$ And lift to drag ratio compare to others.

Finally, I conclude that NACA 2412 wing design with Single slotted flap gives maximum Lift even little compromise with drag. And this wing design can be incorporated as a part of UAV without any problem and even more modification can be done to improve C_l and lift to drag ratio for getting high performance while monitoring.

With this, we change the geometry of wing and increase or decrease angle of attack as our requirements.

X. REFERENCE

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