Kinematic Simulation of Twin Element Airfoil

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Abstract

In modern warfare's UAV's play a major role in both surveillance and combat. Aerodynamic performance is improved using a main element airfoil design where the main surface is used to produce the major lift and the secondary surface is used as a control surface. The preliminary design dimensions as well as relevant loads of the wing structure were calculated based on the design lift and loading requirement for the UAV.

The sizing data is fed in to the solid modeling software to generate the wing components. A necessary bracket has been modeled to simulate the control surface actuation mechanism. The wing design was further analyzed by creating a software model of the UAV wing and simulating the flow and the structural loads using Solid Works and Design Foil software packages. The structural analysis of the UAV wing was performed using an FEA software ANSYS. The CFD analysis of Twin element airfoils is presented for various angles of attack. The primary goal for UAV wing design is the maximization of endurance factor. Twin element airfoil is designed and the kinematic simulation is done for the control surface movement by using Solid works software. In UAV wing which has single element airfoil is divided as leading edge and control surface. But in the twin element airfoil, it has two separate airfoils. The first element is fixed and creates lift force. The second element can be used as Flap and as Aileron, with the help of actuator linkage system. Twin element airfoil is used for the high lift, more endurance, short take off and landing. Improved high-lift performance can lead to increase range and payload, or decrease landing speed and field length.

Keywords: *CFD, Twin element airfoils, UAV wing*

1. Introduction

1.1. Theoretical Background

UAV's are becoming an essential part of the modern defense forces world over in the recent years. The UAVs can be used both for military and nonmilitary purposes including coastal surveillance and monitoring of open burning, illegal logging, piracy, the movement of illegal immigrants, agricultural and crop monitoring, search and rescue, weather observations and tracking cellular phones. The design of low-cost and efficient configurations of UAV are becomes increasingly more important for improving the performances, flight characteristics, handling qualities and UAV operations.

A wing is an airfoil, which has a streamlined cross-section shape producing a useful lift to drag ratio. There are two forces are produced while running of aircraft one is lift and another is drag. The lift to drag ratio is used to compare the aerodynamic efficiency of the different airfoils configurations. The goal is to maximize lift, and to reduce the drag. The primary function of the wing is to generate the sufficient lift force or simply lift (L). However, the wing has the other two productions, namely drag force or drag (D) and nose-down pitching moment (M). While a wing designer is looking to maximize the lift, the other two (drag and pitching moment) must be minimized. In fact, a wing is considered as a lifting surface, that the lift is produced due to the pressure difference between the lower and upper surfaces.

The design of the efficient high-lift systems is very critical for the environmental impact of the UAV's, in terms of the payload and fuel consumption. Wing design for the UAV applications requires a special approach which is different from conventional Man

– operated airplane. Most of next-generation UAVs will require low-cost and efficient configurations. Major performance requirements include stall speed, maximum speed, takeoff run, range and endurance.

This chapter will focus on the detail design of the UAV's wing. The wing can be considered as the most important component of the UAV, without wing an UAV is not able to fly. The most important task in designing a flying wing UAV is the design of the airfoil itself. Since the wing was everything, then the airfoil must be carefully designed. The most important an aerodynamic characteristic in flying wing airfoil is to have the coefficient of moment is to be zero or close to zero. But in the twin element airfoil, it has two separate airfoils. The first element is fixed and creates lift force. The second element can be used as Flap and as Aileron, with the help of actuator linkage syste The factors which are taken in to account during the design are high lift capabilities, short take off and landing, long endurance and reduce drag characteristics. Design of two element airfoils has to take some additional parameters that are not present for single element airfoils. The wing must produce sufficient lift while generating minimum drag, and minimum pitching moment. These design goals should be collectively satisfied throughout all UAV operations and missions.

This project can be divided into three major parts namely

(1) Design

(2) Kinematic Simulation

(3) Analysis

Modeling is closely related computer applications which play a major role in science and engineering today. They help scientists and engineers to reduce the cost and time consumption for research. They are also useful for ordinary people to understand and be trained for something easily.

Modeling is creating a 'model' which represents an object or system with its all or subset of properties. A model may be exactly the same as the original system or sometimes approximations make it deviates from the real system. Modeling can reduce the cost of a process and make the progress faster.

The entire modeling of the UAV wing was carried out in Generative part design of solid works V10. The Generative part design workbench allows us to quickly model both complex and simple shapes using wire frame and surface features. It provides a large set of tools for creating and editing shape design and when combined with other products such as part design it meets the requirements of solid based hybrid modeling.

1.2. Twin Element Airfoil

The twin element airfoil provides higher level of maximum lift because of air flow acceleration through control surface and interaction with upper boundary layer coming from the main element.

The first element is fixed and creates lift force. The second element can be used as Flap and as Aileron, with the help of actuator linkage system.

3.2.1 Difference between Sing le Element and Twin Element Airfoil

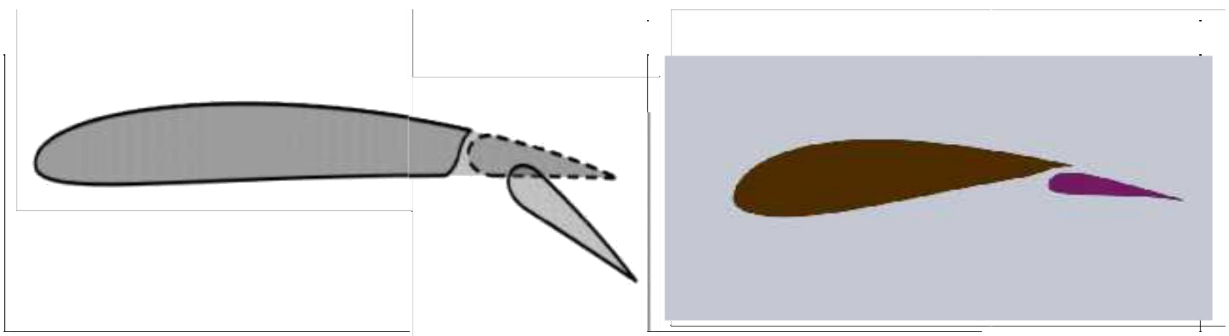


Figure 1.Singl e element and Twin element airfoil differenc e

1.3. Designing Of Airfoil

Airfoil plays major rol e for UAV wing and creating a new airfoil is a challenging task in engineering field. T he lift force component is mainly influenced by the aerodynamic qualities of air foils and can change drastically to accom modate with a variety of functions like mobility, speed, or gliding depending on the pu rpose the UAV. Thus, the first initial consideration in airfoil selection was coefficient of lift. This is the lift coefficient which the airfoil provides the best lift to drag ratio (L/D). Airfoils produce lift by changing the velocity of the air passing over and under itself. B y changing the airfoil angle of attack the air v elocity changes as it travels slower over the top of the wing and travel faster underneath th e wing. Bernoulli's law of pressure equation states that the lift is generated by the press ure difference between the upper and lower surface of the airfoil. When the fluid passes through the leading edge of the airfoil, it speeds up. Twin element airfoil is a new idea for an UAV wing, for the twin element airfoil co-ordinates which are modulated and made as new airfoil. The airfoil which is designed as a twin element and it is separated by main element and control surface airfo il, co-ordinates which made for a two separate airfoils. The co-ordinates for x, y and z axis which are added the values to locate an airfoil on a particular place. Then the coordinate values are calculated for both the root a nd tip airfoils. Finally the original airfoil co-ordinates are imported on solid works softw are to make as twin element airfoil.

1.4. Extruded Wing

Wings develop the major portion of the lift of an UAV. The UAV included considerations into the type of wing and wing placement that would best suit the needs of a high performance UAV. The airfoil which created is extruded in separately as main element and control surface by using solid works software. The extruded airfoil is solid body. The main element is cut a three sections like star board, centre section and port side wing. The second element is cut a various sections like inboard and outboard flaps, inboard and out board aileron, centre section. The cutter sections used for kinematic simulation. The second element act as a control surface.

To initiate the design process, the physical parameters are first identified. There are two types of parameters, dimensional and design. Dimensional parameters basically refer to sizes of the wing. They are resolved in the optimization process, leaving the design parameters to be worked out.

3.6.2 Spar

The main center beam of the wing, designed to carry the structural loads and transfer them by attachment to the fuselage, or body, of the UAV. The main structural member in the wing is the main spar. A "**C"** section composite beam is selected for the main spar. The flanges of C section are called spar caps and the web is called the shear web. As the name indicates the shear loads are carried by the spar web and the bending moments by the spar caps.

The main spar must transfer wing bending moment and the corresponding shear loads along its length to where it attaches to the fuselage and across the center of the aircraft. In a two spar construction, the rear spar must be positioned as aft as possible, but is limited to being in front of trailing edge flaps, control surfaces, and spoilers and their operating mechanisms.

Wing Root

The wing root is the portion of the wing that attaches to the fuselage, or body of the UAV.

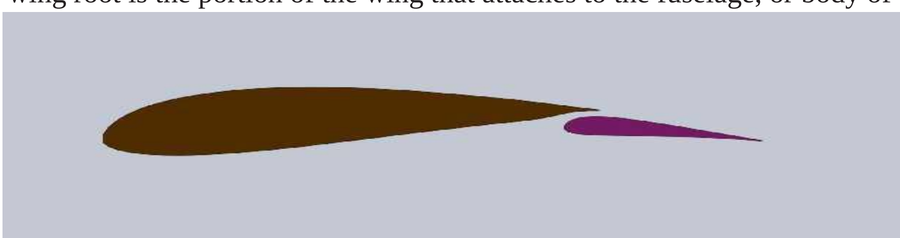


Figure 2. wing Root

Wing Tip

The wing tip is furthest from the fuselage and is typically where the navigation lights are mounted (a red light on the left, a green light on the right).

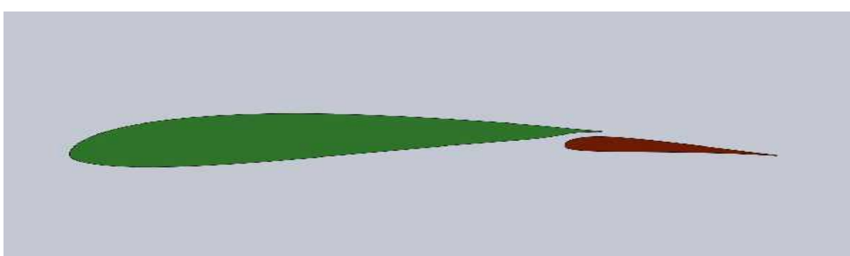


Figure 3. Wing tip

2. Materials and Methods

2.1. CFD Solution Methodology

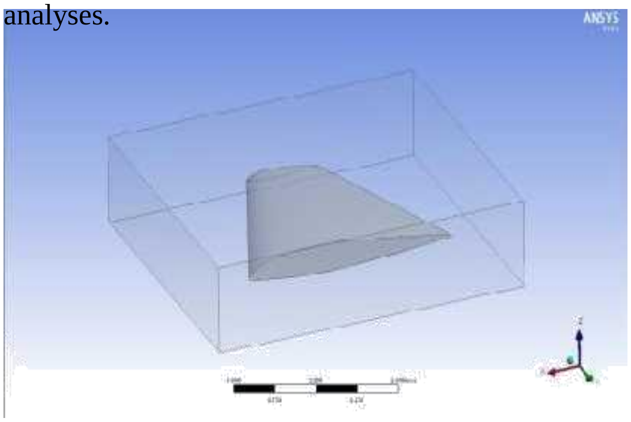
The accuracy of numerical solutions depends on the quality of the discretization used. It is important to bear in mind that numerical results are always approximate. Discretization errors can be reduced by using more accurate interpolation or approximations or by applying the approximations to smaller regions, but this usually increases the time and cost of obtaining the solution. Compromise is needed in solving the discretized equations. Direct solvers, which obtain accurate solutions, are not very used because they are too expensive.

The mock-up geometry was rebuilt with ANSYS Design Modeler and solid works starting from scanned digital model (STL format).

2.2. CFD Approach & Methodology

A CFD Approach & Methodology Development of aircraft geometry involves derivation of geometrical equations of the aircraft. Some parameters such as wing area, sweep angle, taper ratio for each section, span and chord for various span wise locations must be determined. These design parameters are then translated into a 3D model in solid works modeling software, to get the virtual model of an UAV aircraft wing.

Second stage involves conversion from three dimensional solid works CAD model into CFD element using ICEM CFD to create discretized model for CFD analysis. Then, the discretized model was exported to CFX for the analysis. Airflow over the wing was analyzed by defining appropriate boundary conditions. Pressure distribution on the surface of the wing of aircraft was estimated. The surface pressure distribution data was used for calculations of aerodynamics characteristics of wing such as coefficient of lift 'CL' and coefficient of drag 'C' at various angle of attack 'a'. Flow visualization module in the Post Processor of CFX was used to locate the critical area with possible turbulence reduction. The commercial computational fluid dynamics (CFD) software ANSYS/FLUENT is employed for the aerodynamic analyses.



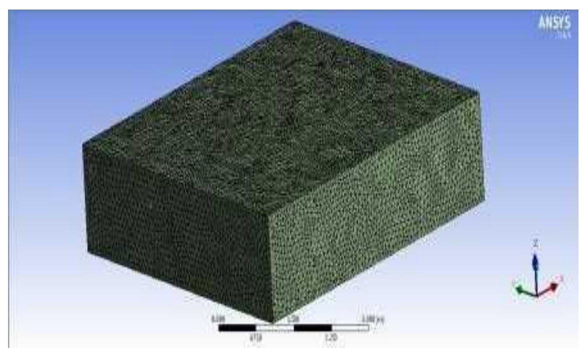
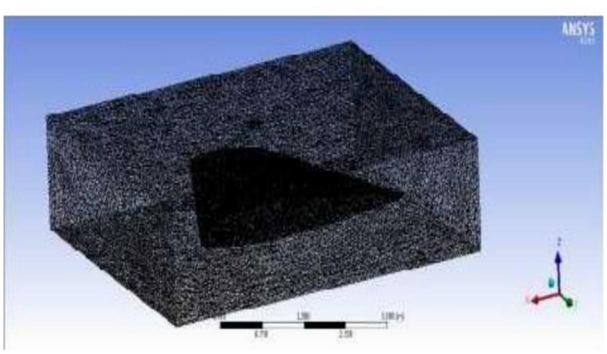


Figure 4. Enclosure of control surface **Figure 5. Meshing**

Statistics	
Nodes	144675
Elements	770080



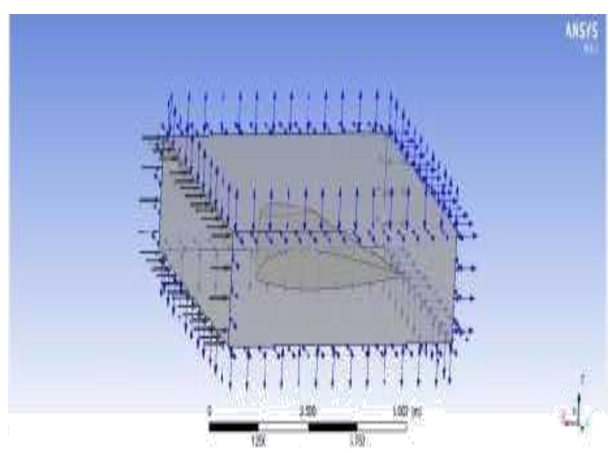


Figure 5. Wireframe Meshing **Figure 7. Setup of control surface**

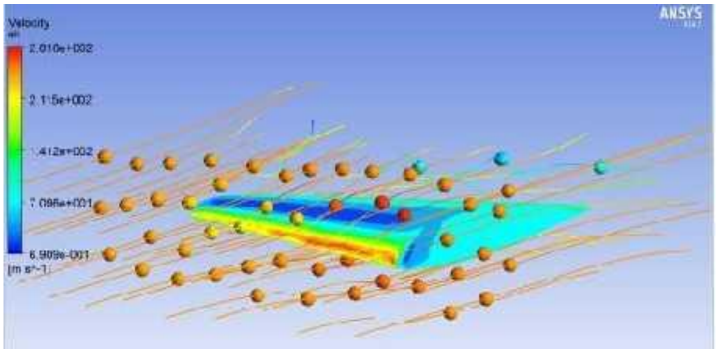


Figure 8. Flow analysis of air molecule on control surface

3. Results and Discussion

3.1. CFD Analysis of Control Surface

In CFD Analysis, we change the altitude, and with increase the angle of attack, we get some cases. The cases are discussed below where the 3 important factor are calculated that is pressure, drag force and lift force. Due to these forces we take so many cases for different angle of attack and the drag and lift force are rise but a point will come where the drag and lift force values will decrease. So let see the cases-

Angle of attack = 0^0

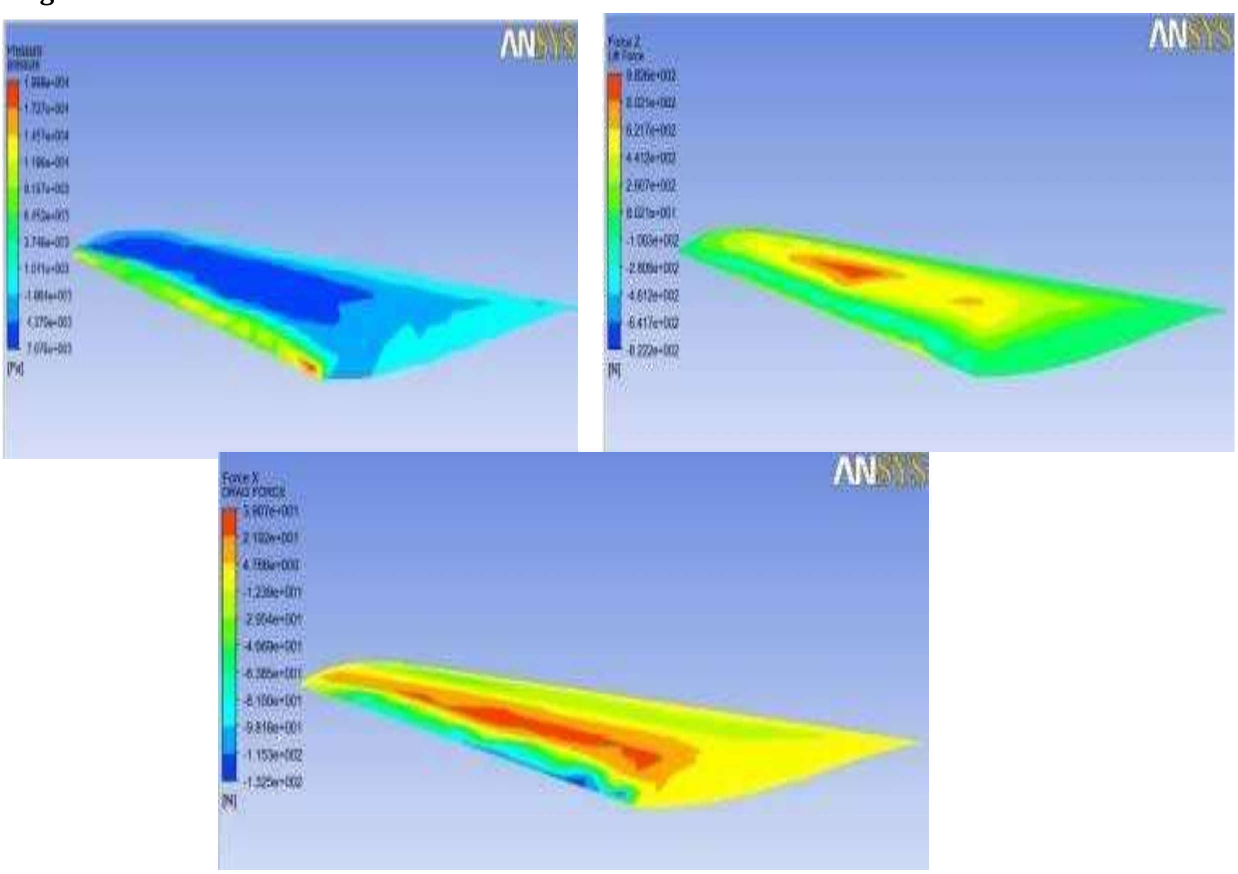


Figure 9. Angle of attack = 00

Angle of attack = 5^0

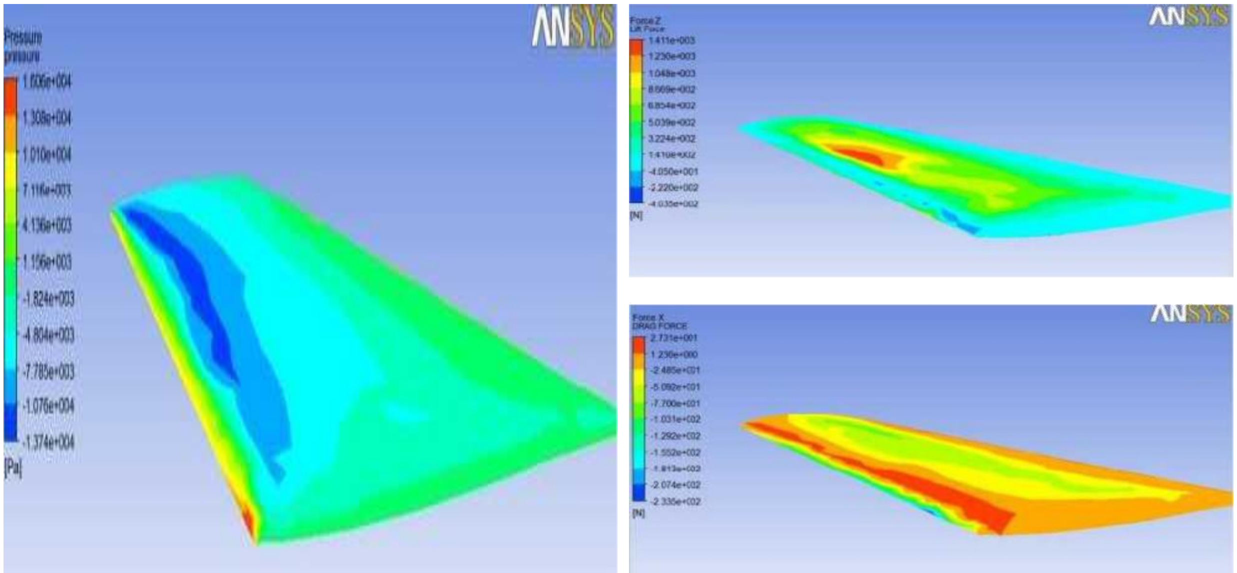
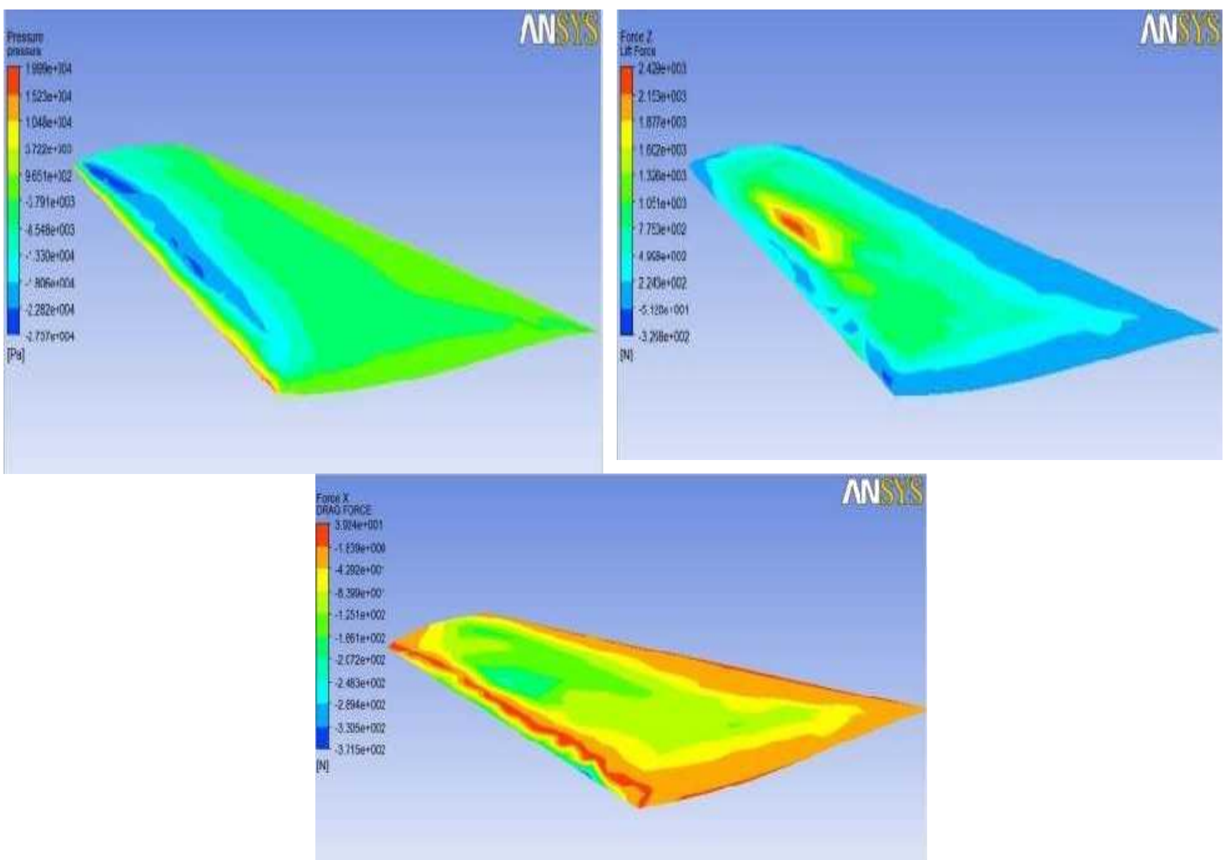


Figure 10.Angle of attack = 50

Angle of attack = 10^0



4. Conclusion

The main objective of this work was the d e s i g n , modeling and kinematic simulation of control surface of an UAV wing. The entire project can be divided into two phases. The first phase is the design and modeling of the UAV wing in solid works - 2010. The second phase is the kinematic simulation of control surfaces in solid works – 2010.

The goal of achieving an endurance and high lift wing design methodology for unmanned aircraft has been modeled. The modeling and kinematic simulation of a new airfoil to be employed on a UAV with short takeoff and landing is Presented. As the drag is reduced, the lift will likely increase. Proposed wing provides not only high maximum lift, but may reduce drag for cruise flight flap flight, by using retracted flap position. Low drag for cruise speed flight provides increased mission range, while high-lift characteristics provide STOL capabilities.

This project report represents a conceptual design approach of a medium weight surveillance type UAV wing in a chronological order including the structural linear static analysis to defy the undecidability of the CAD model of the proposed UAV wing. Software aided flow analysis is also implemented to understand the behavior of the flow over the wing surface including pressure, lift and drag force etc. Substantial steps of construction are also proposed in this report. Through this report, an attempt has been made to understand an idea about the design approach of an aircraft wing through the study on an UAV wing. The standout point of this project is that it attempts to conduct a dedicated study on overall aspect and illustrates details about the concepts of the UAV wing.

CFD helps engineers to find a nearly accurate approximate solution to the governing equation for a range of fluid flow problems.
To optimize the Design the designers should be aware of the application of high lift systems and techniques to engineering systems to improve the UAV endurance level. Skilled designers utilize their knowledge, experience, and judgment to specify these variables and design effective engineering systems.

An entire graduate-level project effort could be dedicated exclusively to defining technology trends. Potential emphasis can be placed on future UAVs based technology trends. Through this project we get a wide knowledge about the UAV. The ENDURANCE of UAV is totally depending up on the AIRFOIL design parameters.

Future Work

Based on investigations toward the design of a wing with a twin element airfoil is considered to meet the requirements of a high performance UAV for the modern defence. Thus, due to a better understanding of emerging technology the design has provide a detailed overview of the growth potential a feasible design integration of an aerodynamic high lift vehicle with sufficient UAV time to complete a military Intelligence Surveillance and Reconnaissance (ISR) mission. The report presently details the design, modeling and Kinematic simulation of control surface of an UAV wing. After the design various modifications will be considered which include using a change aspect ratio, improve high lift devices and less dihedral for higher mobility. So, the futuristic approach is to ENDURANCE of UAV using various type of AIRFOIL with same existing design data. Future design efforts could focus on high lift benefits gained though integration of advanced technologies.

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