CFD Analysis of an Aircraft delta wing

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ABSTRACT

In this paper found the drag and lift forces of aircraft delta wing using CFD. In experimental setup, the design model has to place in testing; this process is quite difficult & cost more than CFD techniques cost for the same. Thus the entire analysis gone through computational fluid dynamics method .The analysis of the two dimensional subsonic flow over a NACA 64A206 airfoil at various angles of attack and operating at a Reynolds number of 3.57×E+06 is presented. The CFD simulation results show good agreement with theoretical values it leads to recommend an optimized wing.

Keywords: lift and drag force, creo wing model, pressure coefficient, CFD analysis, Angle of attack.

INTRODUCTION

From the development of the first powered flights (1903) to the present time, the study of the aerodynamic design has played an important role in the airplanes optimization. Traditionally it has been in the hands of the designer's experience, tests of flight and wind tunnel experiments, being this last tool the one that has provided a method of systematic study and the capability of making inexpensive adjustments of control parameters in a design. At the present time, Computational Fluid Dynamics (CFD) has come to complement the experimental studying, reducing the cost in tests and time for the generation of prototypes.

The selection of right wing is the most important aspect of airplane design which determines lift force generation, maneuverability stall angle, fuel storage. Delta wings finds its application for flying at supersonic speed and hence used for fighter aircraft and space shuttles. Delta wings also provide benefits of swept wings (decreased drag at supersonic speeds) due to their high sweep, and they are structurally efficient and provide a large internal volume which can be used for fuel tanks. They are also relatively simple and inexpensive to manufacture. At this point in the design process CFD analysis plays a crucial, if not its most important, role. Wind tunnel models are generally very expensive to build, costing perhaps hundreds of thousands of dollars or more, and wind tunnel test time is a significant cost driver during a project. In this work we worked on CFD Analysis of delta wing of a fighter aircraft that is F-16 (Felcon Fighter) which is basically used by USA. We analyse the wing of this aircraft on CFD.

INTRODUCTION OF CFD ANALYSIS OF DELTA WING:-

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. On-going research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

The fundamental basis of almost all CFD problems are the Navier–Stokes equations, which define any single-phase (gas or liquid, but not both) fluid flow. These equations can be simplified by removing terms describing viscous actions to yield the Euler equations. Further simplification, by removing terms describing vortices yields the full potential equations. Finally, for small perturbations in subsonic and supersonic flows (not transonic or hypersonic) these equations can be liberalized to yield the liberalized potential equations.

Literature review

Karna S. Patel et al. (1) studied the CFD analysis of the flow over NACA 0012 airfoil and conclude that at the zero degree of AOA there is no lift force generated. The amount of drag force and value of drag coefficient also increased but the amount of increment in drag force and drag coefficient is quite lower compare to lift force.

In this study, NACA 2412 airfoil [2] is used to design the wing, in which the first digit is the maximum camber in hundredths of the chord, the second digit is the location of the maximum chamber from the leading edge in tenths of the chord, and the last two digits represent the maximum thickness in hundredths of the chord [3]. The parameters are chosen, such as airfoil chord c = 0.3m, airfoil span l = 1.6m . These dimensions are used to fabricate the experimental wing model, which are also consistent with the open data of a number of test UAVs samples in Vietnam.

Lift and drag forces were defined due to fluid-structure interaction [4]. The force components that which correspond the velocity inlet are collected. From these data, two graphs of the relationship between lift, drag versus relative velocity between the wing and the airflow are shown in Fig. 9, and Fig. 10, respectively.

The standard technique in evaluating the lift and drag coefficients from an Euler CFD solution is to integrated the pressure on the surface [5]. As seen in Chapter 3, this method does not work for calculating the drag coefficients (all but one drag value was negative). This error occurs because the aircraft surface is represented by triangles; therefore high grid resolution must be used in order to accurately represent curved surfaces [6]. Also, errors are introduced from the subtraction of two large forces in the flow direction. Therefore, the pressure distribution must be accurately known in order to determine the drag force [7]. These two problems suggest that in order for a surface integration technique to be accurate, a fine computational grid must be used, resulting in long run times. Another problem with surface integration technique is that they combine different drag components into one resultant drag coefficient. It is important, especially in conceptual design, to know how the drag is being produced so the aircraft can be efficiently designed [7].These limitations of the surface integration technique have led researchers to look at other methods to evaluate the lift and drag coefficients generated by CFD. One method is the Wake Integration technique. In this method, the drag is computed from the physical phenomenon that causes drag forces [7]. This is done by evaluating the vortex and entropy produced on a plane perpendicular to the flow which lies downstream from the aircraft [6]. The vortices produced are results of the lift induced drag, and the entropy production is related to the wave drag [8]. Thus, this method will be used in this analysis since it is not as dependent on the grid resolution as surface integration, and it separates the drag components by the physical phenomena that create the drag.

WINGS NAD ITS PARAMETER

ABOUT THE WING:-

A wing is one of the arms –like limbs of aircraft which it usually uses in flying, or one of the similar limbs of an insect. The wing may be considered as the most important component of an aircraft, since a fixed-wing aircraft is not able to fly without it. Since the wing geometry and its features are influencing all other aircraft components, we begin the detail design process by wing design. The primary function of the wing is to generate sufficient lift force or simply lift (L). However, the wing has two other productions, namely drag force or drag (D) and nose-down pitching moment (M).

DELTA WING:-

The delta wing is a wing shaped in the form of a triangle. The delta wing suffered from some undesirable characteristics, notably flow separation at high angle and high drag. Actually the name of the delta because of its design is look like Greek symbol delta. The generally use of delta wing is in the fighter aircrafts like, Tejas, F-16 felcon fighter etc. The delta wing specially designed for the fighter planes for having max. Speed and taking cruise and loiter. In this project actually we are worked on the delta wing.

The wing is selected that is delta wing, whose Mach no. is 1.5 that is subsonic.

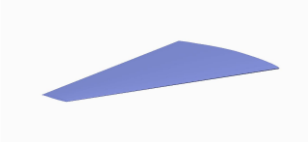


Fig. 1.0 Delta wing

WING PARAMETER

In design and analysis of wing, the wing parameters play an important role. The wing parameter gives the actual operations about the wing analysis. Some wing parameters are-

- Wing reference (or plan form) area (Sref or S)
- Number of the wings
- Vertical position relative to the fuselage (high, mid, or low wing)
- Horizontal position relative to the fuselage
- Cross section (or airfoil)
- Aspect ratio (AR) Taper ratio
- Tip chord (Ct)
- Root chord (Cr)
- Mean Aerodynamic Chord (MAC or C)
- Span (b)
- Twist angle (or washout)
- Sweep angle
- Dihedral angle
- Incidence etc.

AIRFOIL SELECTION:-

The airfoil, in many respects, is the heart of the airplane. The airfoil affects the cruise speed, takeoff and landing distances, stall speed, handling qualities, and overall aerodynamic efficiency during all phases of flight. It is appropriate to claim that the airfoil section is the second most important wing parameter; after wing plan form area. The shape of such an important component of the aircraft makes a lot of impact on its movements. This shape is what is called an airfoil.

According to NACA the airfoil design is most important thing in aircraft, the airfoil by means of cross section of wings. The NACA have some special standards for every airfoil design, as F16 have the code is 64A204 or 64A206. Due to this code we can get the overall profiles of airfoil. It is appropriate to claim that the airfoil section is the second most important wing parameter; after wing plan form area. The airfoil section is responsible for the generation of the optimum pressure distribution on the top and bottom surfaces of the wing such that the required lift is created with the lowest aerodynamic cost (i.e. drag and pitching moment).

The primary function of the wing is to generate lift force. This will be generated by a special wing cross section called airfoil. Wing is a three dimensional component, while the airfoil is two dimensional section. Because of the airfoil section, two other outputs of the airfoil, and consequently the wing, are drag and pitching moment. The wing may have a constant or a non-constant cross-section across the wing. Drag coefficient must be minimum. Both of these coefficients are mainly coming from airfoil section.

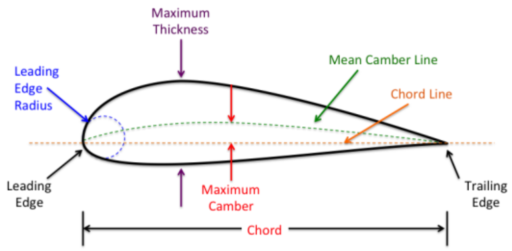


Fig. 2.0 Airfoil geometric parameters

AIRFOIL DESIGN:-

In the airfoil design we use the parameter of NACA 6 series that is NACA- A64-206 or NACA- A64-204.

This six series gives us a different way to design the airfoil. The standard airfoil of F-16 is-

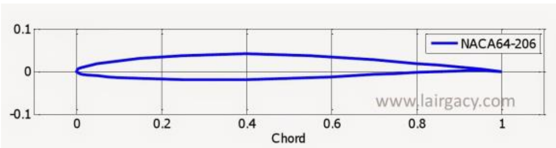


Fig. 3.0 F-16 Airfoil

This airfoil help us to design a wing airfoil of a F 16 aircraft, and the our design is calculated by the reference of NACA airfoil selection parameters.

METHODOLOGY:-

In all of these approaches the same basic procedure is followed. During pre-processing the geometry (physical bounds) of the problem is defined. The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform. The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation. Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined. The simulation is started and the equations are solved iteratively as a steady-state or transient. Finally a postprocessor is used for the analysis and visualization of the resulting solution.

The calculating data are-

- Wing Area= 600sq ft.
- Span=32ft 48inch
- Aspect Ratio= 1.750
- Taper Ratio=0.100

These data are calculated from the formulas of NACA

Meshing and analysis: - Import and enclosure

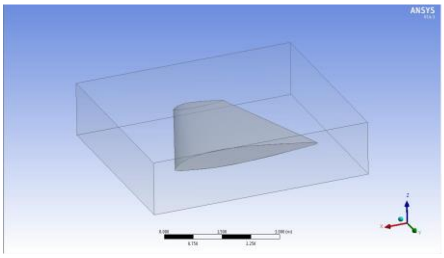


Fig. 4.0 Enclosure of delta wing

Meshing

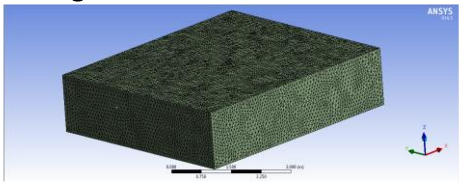


Fig.5.0 Meshing

Meshing: wireframe model

Statistics	
Nodes	144675
Elements	770080

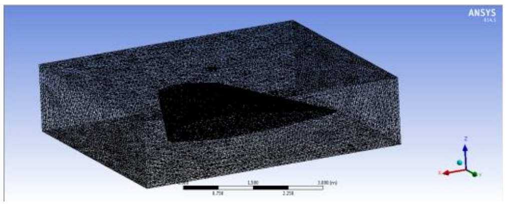


Fig.6.0 Wireframe Meshing

Setup

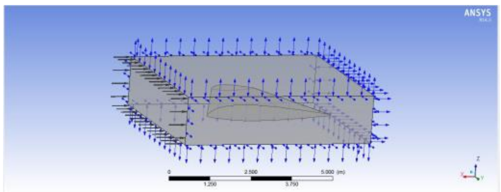


Fig. 7.0 Setup of delta wing

Flow of air molecule on delta wing

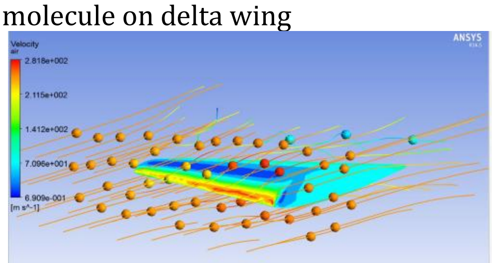


Fig. 8.0 Flow analysis

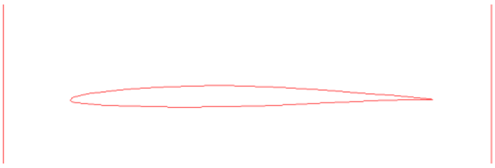


Fig. 9.0Airfoil of first prototype NACA 64A206

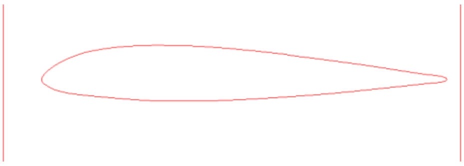


Fig. 10.0AIRFOIL OF SECOND PROTOTYPE NACA FALCON

RESULTS

CREO MODELLING OF DELTA WING:-

Fig. 11.0 delta wing

CFD ANALYSIS OF DELTA WING:-

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 fore values will decrease. So let see the cases-

CASE 1-

Angle of attack = 0^0

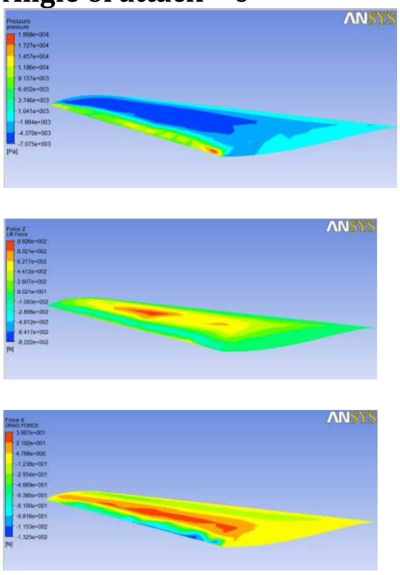


Fig. 12.0 Angle of attack

Angle of attack = 5^0

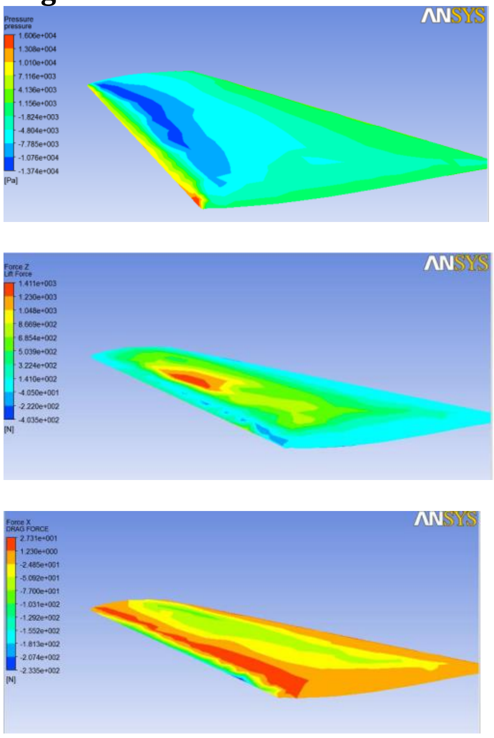


Fig. 13.0 Angle of attack = 5^0

Angle of attack = 10^0

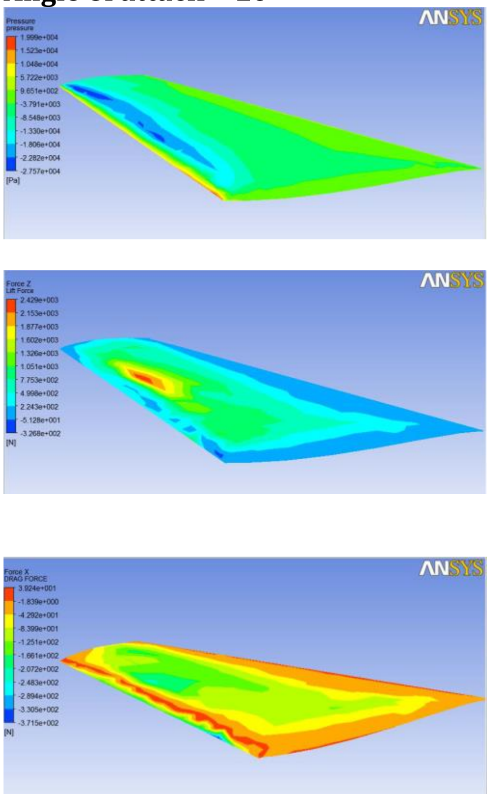
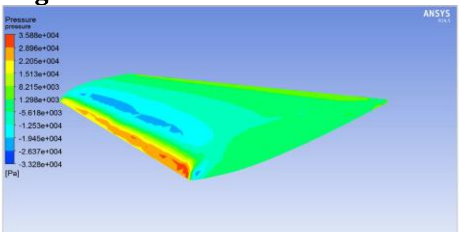
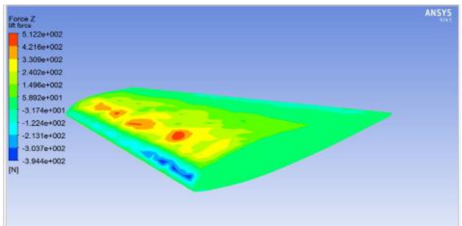


Fig. 14.0 Angle of attack = 10^0

CASE 2-

Angle of Attack: 0^0





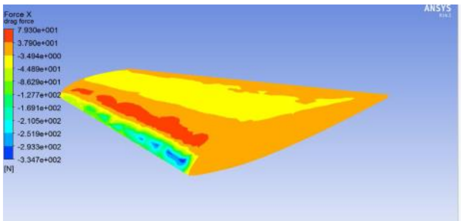
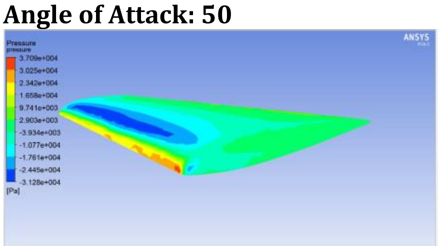
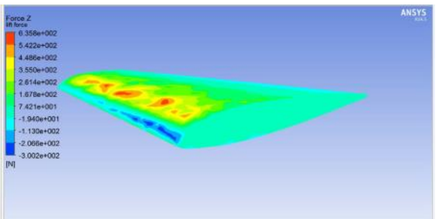


Fig. 15.0 Angle of attack = 0^0

Angle of Attack: 50





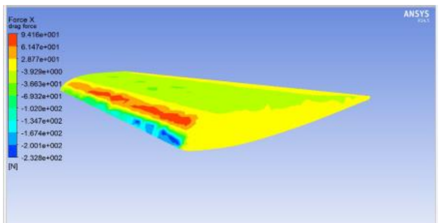
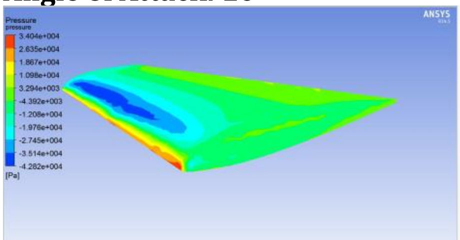
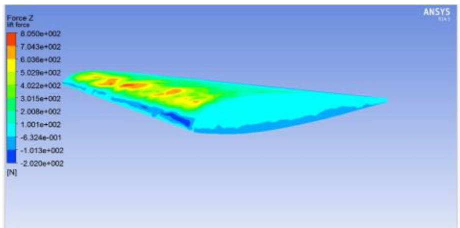


Fig. 16.0 Angle of attack = 5^0

Angle of Attack: 10^0





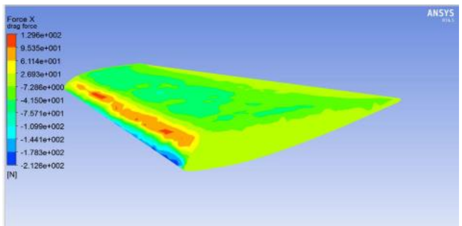


Fig. 17.0 Angle of attack = 10^0

Data Table No : 1
FOR CASE -01

S. NO.	ANGLE OF ATTACK (α)	PRESSURE N/m2	LIFT FORCE N	DRAG FORCE N
01	α = 00	19960	982.6	39.07
02	α =5 0	16060	1411	27.31
03	α =100	19990	2429	39.24
04	α=150	25200	3421	47.02
05	α=200	31550	4557	50.01
06	α=250	37760	5201	60.05
07	α=260	38230	5286	86.19
08	α=280	40130	5315	96.15
09	α=290	42280	5226	103.1
10	α=300	45740	4792	197.7

FOR CASE -02

Data Table No : 2

S. NO .	ANGLE OF ATTACK (α)	PRESSURE N/mm2	LIFT FORCE N	DRAG FORCE N
01	α = 00	35880	512.2	79.30
02	α =5 0	37090	635.8	94.30
03	α =100	34040	805.0	129.6
04	α=150	33370	1025	157.7
05	α=200	38550	1431	225.8
06	α=230	40210	1690	273.7
07	α=260	40680	1837	274.1
08	α=300	44420	2062	259.2
09	α=320	44970	2127	224.6
10	α=330	46520	1941	251.0

CONCLUSION:-

In present scenario the aircrafts are very important for any country, and mostly fighter aircraft. But every country keeps the details (Information) of the fighter aircrafts are very confidential for safety purpose. In India DRDO is also keeps the all information about its fighter aircrafts. In our project we studied on CFD analysis of delta wing, as we know that delta wings aircraft are either subsonic or supersonic, it gives high speed in normal altitude In this project we studied on two models of delta wing, and we got the result that the first prototype is better than second because it's drag force and lift force is better than second case.

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