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Design and Aerodynamic Analysis of Different Empannages

Md Khaleel
Assistant Professor,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

V Mallesh
M.Tech Student,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

Dr. M Satyanarayana Gupta
Professor & HoD,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

ABSTRACT

The Project deals with the design and analysis of Empennage. Empennage is the various arrangements of vertical stabilizer and the horizontal stabilizing surfaces at rear part of an airplane. An airplane's tail design is important because it stabilizes and controls the airplane in both up-and-down movements of pitch and side-to-side movements of yaw.

The all tail functions are same with respect to their stabilizers such as vertical and horizontal. The controls of the vertical stabilizer is Rudder, it controls the yaw movements. Horizontal stabilizer control surfaces are Elevators, and it controls the pitch movements. Study of different types of empennage is carried out and the suitable configuration is selected.. The design is carried out from the initial stage of airfoil performance static analysis, optimizing the best suitable airfoil for the aircraft.

By using ANSYS ICEM CFD we get the results of the various tails mainly conventional tail, T tail , V tail. Through this software we can evaluate results and that the best configuration and aerodynamically efficient then we can conclude the best tail configuration to aircraft.

INTRODUCTION

In this documentation we introducing fundamentals that govern the tail performance, techniques and procedure to design and CFD analysis over the horizontal tail and vertical tail will be provided. At the end of the chapter a fully solved example that illustrates the implementation of the design technique will be presented by the results. Horizontal tail and vertical tail (i.e. Tails) along with wing are referred to as lifting surfaces. This name differentiates tails and wing from control surfaces namely aileron, elevator, and rudder. Due to this name, several design parameters associated with tails and wing; such as airfoil, plan form area, and angle of attack; are similar. Thus, several tails parameters are discussed in brief. The major difference between wing design and tail design originates from the primary function of tail that is different from wing. Primary function of the wing to generate maximum amount of lift, while tail is supposed to use a fraction of its ability to generate lift. If at any instance of a flight mission, tail nears its maximum angle of attack (i.e. Tail stall angle); it indicates that there was a mistake in the tail design process.

Empennage structure evolves essentially as does the wing. The aspect ratio of either a vertical surface or a horizontal surface usually tends be smaller than a wing aspect ratio. The low aspect ratio of course, means less bending moment because of less span. To date, the aero dynamist has not been able to make a case for a leading edge device on an empennage surface. Reliability of the controls, plus controls and structural weight, tradeoffs, favour the use of larger surfaces rather than the complication of leading edge devices. With no devices, the leading edge can be included in the torque box torsional calculations, since it is not all cut up with a slat or flap. The type of construction employed in the fixed control surfaces, stabilizer, and fin is usually similar to the types of wing constructions.

1. Tail configuration
2. Horizontal tail horizontal location with respect to fuselage(aft tailorcanard)

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Horizontal tail

3. Plan form area(S_h)
4. Tail arm (l_h)
5. Airfoil section
6. Aspect ratio (AR_h)
7. Taper ratio (□$_h$)
8. Tip chord (C_{h_tip})
9. Root chord (C_{h_root})
10. Mean Aerodynamic Chord (MAC_horC_h)
11. Span (b_h)
12. Sweep angle (□$_h$)
13. Dihedral angle(□$_h$)
14. Tail installation
15. Incidence (i_h)

Vertical tail

16. Plan form area (S_v)
17. Tail arm (l_v)
18. Airfoil section
19. Aspect ratio (AR_v)
20. Taper ratio (□$_v$)
21. Tip chord (C_{t_v})
22. Root chord (C_{r_v})
23. Mean Aerodynamic Chord (MAC_vorC_v)
24. Span (b_v)
25. Sweep angle (□$_v$)
26. Dihedral angle (□$_v$)
27. Incidence (i_v)

LIFT AND DRAG CHARACTERISTICS

The dataset collected for the computation of the tail efficiencies can also be used to determine the tail drag polar. With CLH already available, CDH is calculated also using the LRE method. A set of computations at different □ □ but identical i_H results in one "branch" of the drag polar. If several branches for different i_H are plotted in one diagram, one observes that the branches do not join each other. This is due to different effective □ H for different iH as a change in i_H also results in a change of the HTP position in the wing wake, which in turn results in a different downwash value at the tail. Therefore CLH and CDH must be corrected for □ □ as follows:

$$C_{LH,\,\alpha H} = CLH_{,\,\alpha\,.Cos\,\varepsilon} + CDH_{,\,\alpha\,.\,Sin\,\varepsilon}$$

$$C_{DH,\,\alpha H} = CDH_{,\,\alpha\,.\,Sin\,\varepsilon} - CLH_{,\,\alpha\,.\,Cos\,\varepsilon}$$

COMPARISON OF REFERENCE-, U-, AND V-TAIL CHARACTERISTICS

A considerable part of the aerodynamic investigations in the NEFA project was devoted to the analysis of the tail characteristics by means of CFD. The emphasis of the DLR contribution was put on the cruise flight conditions (M=0.77) at wind tunnel Reynolds numbers (Re=2.7*106). The computation results were then used to compare quantitatively lift and drag characteristics as well as tail efficiencies. Furthermore, flow phenomena were evaluated qualitatively by means of field and surface streamlines cp and cf-distribution etc. As the more phenomenological analysis did not reveal any surprising effects, the part of the work presented here will focus on the quantitative results due to space limitations.

AIRFOIL

An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Subsonic airfoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with a symmetric curvature of upper and lower surfaces. Foils of similar function designed with water as the working fluid are called hydrofoils.

ANSYS ICEM CFD

ANSYS Meshing is the general purpose meshing tool found in the ANSYS Workbench environment. It includes a lot of powerful ICEM and T Grid meshing technology, but exposed in a simplified and automated way. For instance, Multi Zone in ANSYS Meshing is based on ICEM CFD hexa technology, but without the learning curve associated with blocking, edge distributions, etc.

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PRE PROCESSING: DESIGN OF AIRCRAFT GEOMETRY

Dimensions of a Business Jet Aircraft are taken from Text book **Aircraft Design Projects** for engineering students and tabulated in Table 1. But in the project 1/4th of dimensions are taken i.e. a scale ratio of 4:1. NACA 0012 airfoil is used for Tail parts. Designing and Meshing is carried out in ANSYS ICEM CFD module for three Tail configurations.

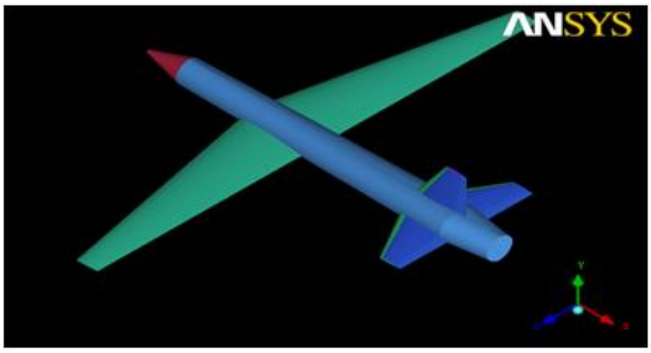
S.No	Part	Length
	Principal Dimensions	
1	Overall length	43.0 m
2	Overall height	13.0 m
3	Wing span	48.0 m
	Wing	
4	Conventional area	216 sq.m
5	Aspect ratio	10
6	Sweep bank	16°
7	Taper ratio	0.3
	Control Surfaces	
8	Horizontal Tail area	20.0 sq m
9	Vertical Tail area	15.5 sq.m
	Fuselage	
10	Fuselage length	40.0 m
11	Fuselage outer diameter	3.6 m
12	Passenger cabin length	22.0 m

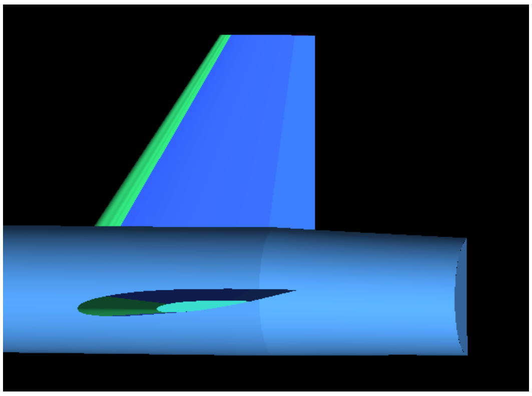
Horizontal tail

- Aspect ratio=4.75
- Sweep angle=17.5^0
- Taper ratio=0.45

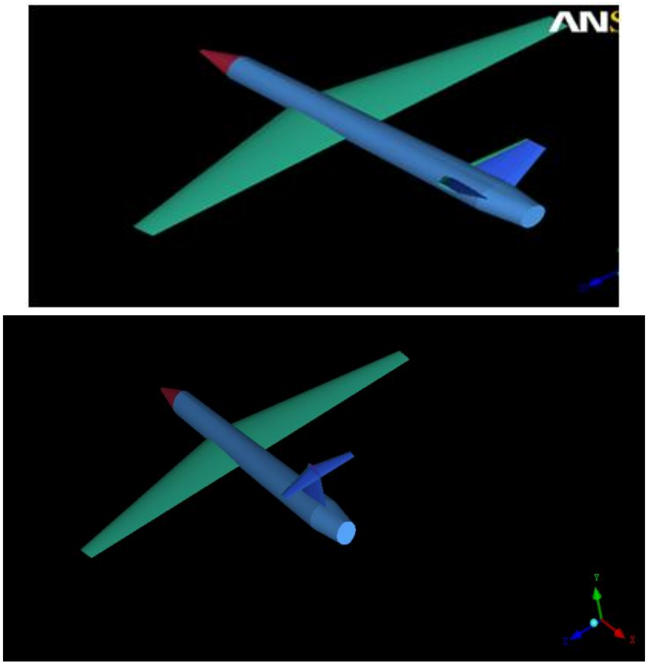
Vertical tail

- Aspect ratio=1.2
- Sweep angle=21.5^0
- Taper ratio=0.58





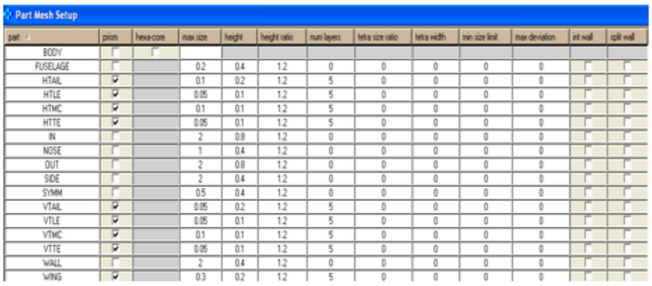
Geometry of the conventional tail



Geometry of the T-tail

MESHING:

Unstructured mesh is created for the problem with total 6-7 lakh elements were created for three configurations.



Part Mesh Setup

part	prism	hexa-core	max size	height	height ratio	num layers	tetra size ratio	tetra width	min size limit	max deviation	int wall	split wall
BODY	☐	☐										
FUSELAGE	☐		0.2	0.4	1.2	0	0	0	0	0	☐	☐
HTAIL	☑		0.1	0.2	1.2	5	0	0	0	0	☐	☐
HTLE	☑		0.05	0.1	1.2	5	0	0	0	0	☐	☐
HTMC	☑		0.1	0.1	1.2	5	0	0	0	0	☐	☐
HTTE	☑		0.05	0.1	1.2	5	0	0	0	0	☐	☐
IN	☐		2	0.8	1.2	0	0	0	0	0	☐	☐
NOSE	☐		1	0.4	1.2	0	0	0	0	0	☐	☐
OUT	☐		2	0.8	1.2	0	0	0	0	0	☐	☐
SIDE	☐		2	0.4	1.2	0	0	0	0	0	☐	☐
SYMM	☐		0.5	0.4	1.2	0	0	0	0	0	☐	☐
VTAIL	☑		0.05	0.2	1.2	5	0	0	0	0	☐	☐
VTLE	☑		0.05	0.1	1.2	5	0	0	0	0	☐	☐
VTMC	☑		0.1	0.1	1.2	5	0	0	0	0	☐	☐
VTTE	☑		0.05	0.1	1.2	5	0	0	0	0	☐	☐
WALL	☐		2	0.4	1.2	0	0	0	0	0	☐	☐
WING	☑		0.3	0.2	1.2	5	0	0	0	0	☐	☐

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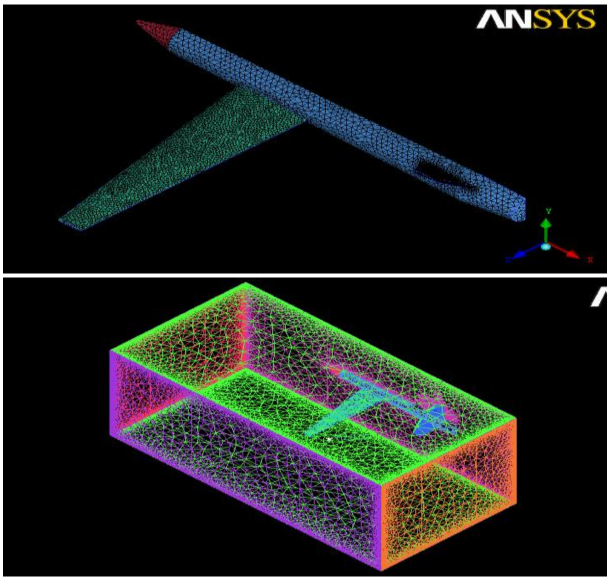
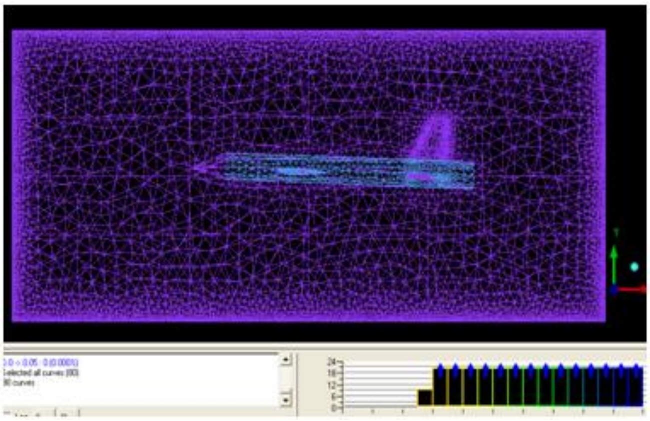


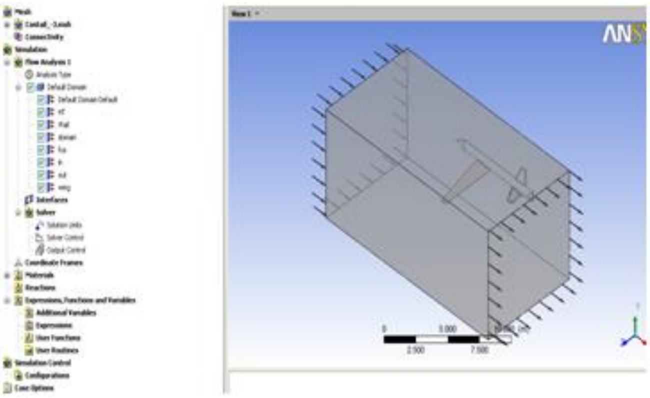
Meshing of whole geometry

Mesh Quality:

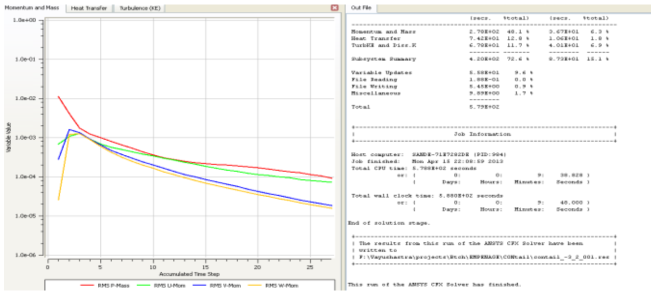


Meshing quality

Boundary Conditions:



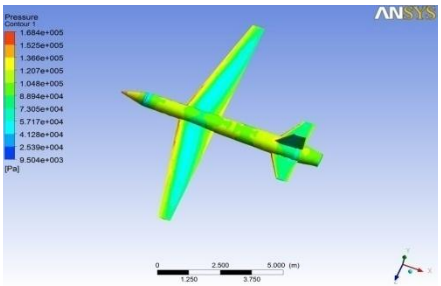
PROCESSING:



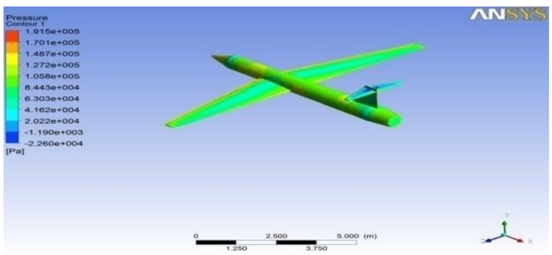
Solution has been converged for 27 iterations at 1.0e+04 as shown in above figure. The above figure shows residuals of continuity and x.y.z momentum equations for every iteration.

POST PROCESSING
CONTOURS:

- Open the result file in CFD-Post
- Select contour from Toolbar
- Insert contour – Name – Pressure – ok
- Geometry – Locations – Select … Location Selector – select Fuselage, Horizontal and Vertical Tail – ok
- Variable – Pressure
- Apply
- The contour is as shown in figure below.



Analysis of conventional tail



Analysis of T-tail

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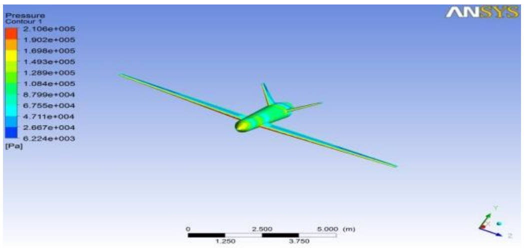
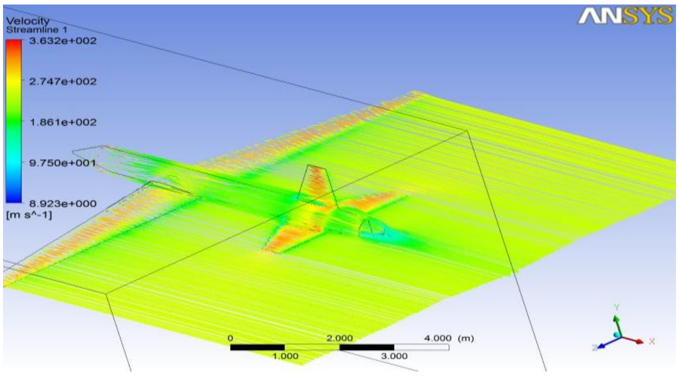


Analysis of VorU-tail

STREAMLINES:

- Open the result file in CFD-Post
- Select Streamline from Toolbar
- Insert Streamline – Name – velocity – ok
- Geometry – Start From – Select … Location Selector – select Fuselage, Horizontal and Vertical Tail – ok
- Sampling – Equally Spaced
- # of points - 1000
- Variable – Velocity
- Direction - Forward
- Apply
- The contour is as shown in figure below.



Stream lines

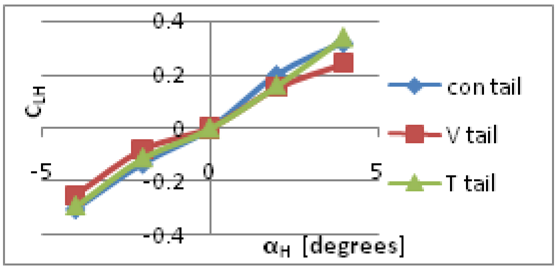
Vectors:

- Open the result file in CFD-Post
- Select Vector from Toolbar
- Insert Vector – Name – velocity – ok
- Geometry – Start From – Select … Location Selector – select Horizontal and Vertical Tail – ok
- Sampling – Equally Spaced
- # of points - 100
- Variable – Velocity
- Projection - None
- Apply
- The vector is as shown in figure below.

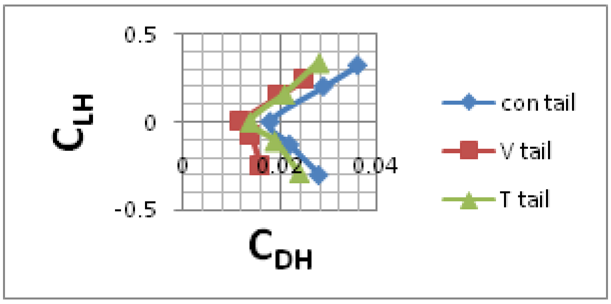
RESULTS AND DISCUSSIONS

Lift and drag characteristics are first compared and evaluated, followed by a section with special emphasis on the analysis of the V-tail design for which trim drag development is investigated and the aerodynamic performance at cruise flight condition is compared with the Conventional tail design.

By following the above procedure for all the cases C_L is calculated and plotted as shown below.



Coefficient of lift(C_L)



Coefficient of lift and drag

Thislinear part of the polar was therefore used to determine the downwash angle. The distribution of C_{LH} vs. α resulting from Eq. (1) is plotted in Figure 2. The lift curve slope is usually taken as a measure for a tail's efficiency. In this regard, Figure 2 indicates that the conventional tail has the highest efficiency, closely followed by the T-tail. This may be attributed partly to reduced aspect ratio of the T-tail HTP. When referencing the lift curve slope based on aircraft conventional values, the two tails are almost identical in performance due to the smaller downwash

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coefficient of the T-tail in comparison to the Conventional tail. The V-tail efficiency on the other hand is noticeably lower, mainly due to the fact that the actual tail surface area is used as conventional area for all configurations while only part of this area acts in the z- or lift direction due to the high dihedral angle of the V-tail (43.1°) in comparison to the other tail shapes (6°). Like in the case of the V-tail, this reduced efficiency or lift curve slope is partly offset by a lower downwash gradient, which can be attributed to the fact that a large part of the V-tail has a greater vertical distance from the wing wake position in the tail area.

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