CFD ANALYSIS OF DELTA WING BODY CONFIGURATIONS AT LOWER ANGLE OF ATTACK

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Abstract - *The delta wing is a triangular wing in the shape of a plant. It is named because of its similarity in shape to the Greek letter delta (Δ). The first practical applications of the delta wing occurred in the form of the so-called "tailless triangle", that is, without horizontal tail. As the angle of attack increases, the leading edge of the wing creates a vortex that induces flow, giving the delta a very large stall angle. Pure delta-wings fell out of favor somewhat due to their undesirable characteristics, notably flow separation at high angles of attack, high drag at low altitudes, low wing loading and poor maneuverability. The design of a modern light fighter, which can traverse, transonally maneuver and stall, requires an additional heavily swept area in front of the main wing, called the leading edge extension (LEX), which results in some changes in the wing, such as tail delta, cropped delta, double delta, cranked arrow and ogival delta.*

The present project work investigates the flow field over a typical cropped delta and double delta wing body configuration at low angles of attack (α) from 0° to 15° with an increment of step 3. Delta wing with sweep angle of 60° and double delta wing with a sweep of 55°/60° having a beveled leading edge are modeled and simulated at Mach number 0.4 and at a Reynolds number (Re) of 2.7x10^4. The flow simulations are carried out by the unstructured hybrid meshes comprising of tetrahedral and prism elements created by ICEMCFD. The meshes are refined adequately to resolve the boundary layer flow. The flow simulations are carried out by ANSYS FLUENT. The aerodynamic characteristics of both the wing body configurations are compared to find which is to be more effective. The computed data obtained is also compared with the available experimental data.

Key Words: C: Wing chord, S: Wing reference, B: Wing span, λ: Taper ratio, A: Aspect ratio

1. INTRODUCTION

The delta wing body configuration consists of a delta wing along with the fuselage so called as body. Pure delta-wings fell out of favour somewhat due to their undesirable characteristics, notably flow separation at high angles of attack and high drag at low altitudes [1]. In order to overcome these undesirable characteristics there were some variations in delta wing design and geometry. They are:

- **Tailed Delta:** added normal tail (with horizontal tail) to improve handling (MiG-21).
- **Cropped Delta:** the tip is cut off. This helps prevent drag at high angles of attack (F-16).
- **Compound delta:** double delta or ulnar boom: the inner wing has a very high sweep while the outer wing has less sweep to create a high lift vortex in a more controlled manner, reduce drag and thus allow the delta to land at an acceptably low speed [4].
- **Ogee delta (ogival delta):** with a smooth curve "ogee" connecting two parts instead of an angle.

The analysis of steady flow is done for a semi half span of wing body configuration at sea level and at Reynolds number of 2x10^5. The analysis is done for five low angles of attack i.e., from 3° to 15° with a step increment of three at a subsonic Mach number of 0.5. The solution obtained for both the wing body configurations are compared to find which is to be more effective. Also the obtained results are compared with the available experimental data.

The present work is based on the computational analysis of flow over delta wing body configurations (cropped delta and double delta) at lower angle of attack of a typical fighter aircraft. Design and analysis of wing body configuration is important for overall aerodynamic performance of an aircraft [3].

2. PROBLEM FORMULATION:

As from the study on Delta wing and as seen in the literature survey the double delta wing body configuration not only increases the lifting area of the wing, but also creates its own leading edge vortices which help to stabilize the flow field over main wing [2]. Therefore double delta wing body configuration produces more lift and is more stable than a cropped delta wing.

We have undertaken this study of flow characteristics over a wing body configuration through CFD simulation and the objectives in this analysis are as follows:

- Study the aerodynamic parameters such as lift coefficient and drag coefficient i.e., (CL and CD).
- Calculate the L/D ratio for both the wing body configurations.
- Compare the two wing body configurations to find which is to be more effective.

In this present work we have made an effort to study the flow characteristics over the double delta having sweep of [2] 55°/60° where there is less difference between the sweep and the strake angle and the cropped delta wing having a sweep angle of 60° with a beveled leading edge are modeled and simulated at Mach number 0.4 and at a Reynolds number (Re) of $2x10^5$. A detailed study has been done at one subsonic Mach number 0.4 for 6° angles of attack from 0° to 15° for both the wing body configurations. The results obtained are compared with each other to find which is to be more effective from the design point of view.

3. GEOMETRIC MODELLING

The modelling of geometry of both the wing body configurations is done using CATIA V5 R20 as follows:

Table 1: Geometrical Specifications

Planform	Cropped Delta Wing	Double Delta Wing
Aspect ratio	4	3.8
Leading edge sweep	60^0	60^0
Trailing edge sweep	0^0	55^0
Taper ratio	0.18	0.203
Twist	0^0	0^0
Root chord	153mm	39mm
Semi span of model	75.256mm	75.26mm

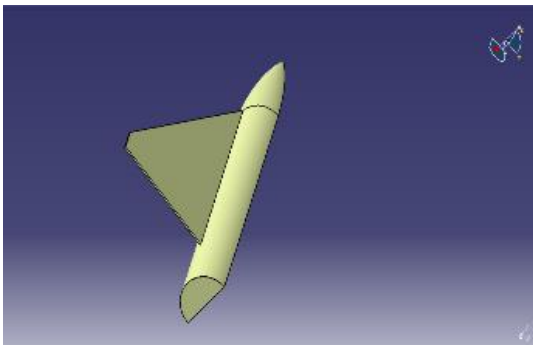

Fig 1: Cropped delta wing body (upper surface)

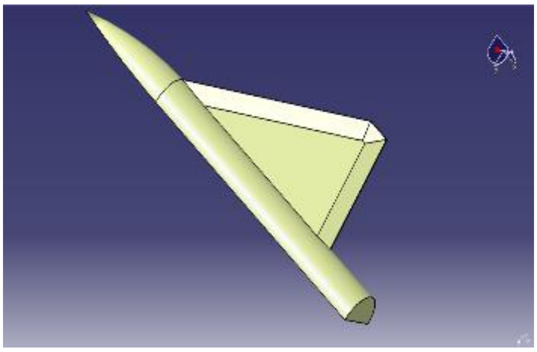

Fig 2: Cropped delta wing body (lower surface)

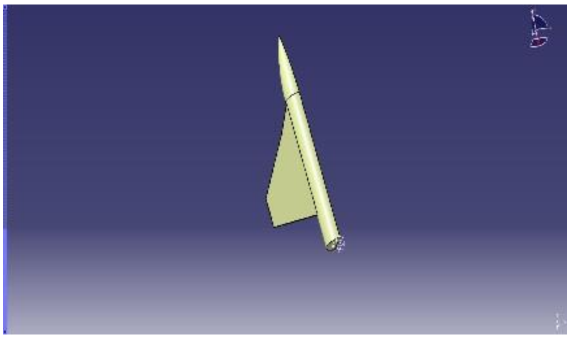

Fig 3: Double delta wing body (lower surface)

4. MESH GENERATION

The model made in CATIA is imported to ANSYS ICEM CFD in ".stp" format. A tetrahedral mesh is generated in the following sequence. A hemispherical domain is created using 'Sphere' option and its cap is created using 'Simple surface'. The domain is segmented into regions and is named appropriately as INLET, OUTLET and WALL. The model is segmented into body, wing upper, wing lower, side lower and faces using 'Segment surface' in order to obtain a clean and quality mesh. The curves are extracted from the surface and extra curves are deleted.

1.1 Boundary Conditions:

There are a number of common boundary types.

INLET:

Inflow: carried variables specified in the boundary, or by a predefined profile, which performs the initial fully developed calculation of the one-dimensional flow.

Stagnation (or reservoir): Total pressure and total temperature (in a compressible flow) or total pressure (in an incompressible flow) are fixed. Normal inflow condition for compressible flow.

OUTLET:

Outflow: Zero normal gradient for all variables.

Pressure: As for the flow, except for the fixed pressure value; normal output state in compressible flow if output is subsonic.

Radiation (or convection): Prevents reflection of wave motions at output stream boundaries by solving a simplified first-order wave equation with output wave velocity.

WALL:

Non-slip wall: default case for solid edges (zero velocity with respect to the wall stress calculated using the viscous stress expressions or the wall function).

Slip wall: only the speed component normal to the wall disappears. Used when it is not necessary to convert a thin boundary layer to an insignificant wall boundary.

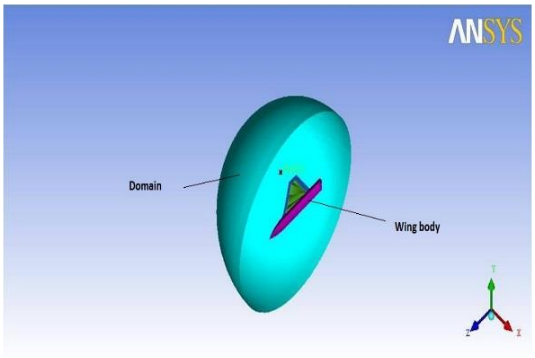

Fig 4: Segmented model with domain without cap

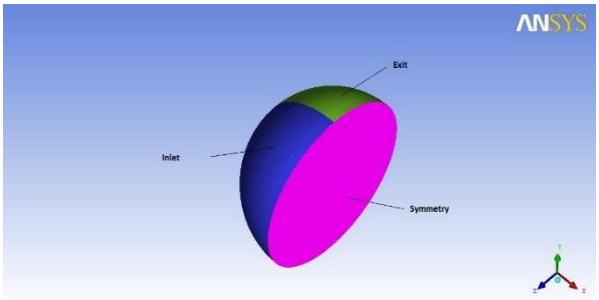

Fig 5: Segmented domain with cap

Under the part mesh setup the element size is set to 30 which yields 15,00,000 elements and the type of element is chosen to result in a tetrahedral mesh.

Thus the tetrahedral mesh is generated as shown below

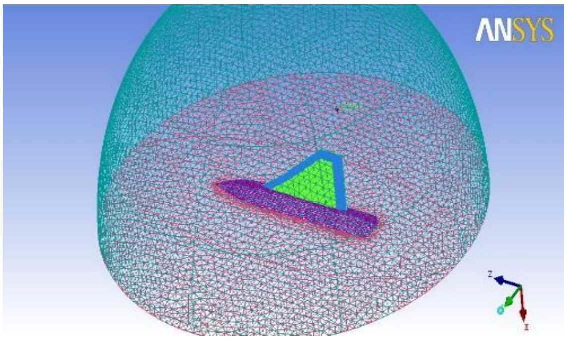

Fig 6: Meshed model of double delta wing body with domain

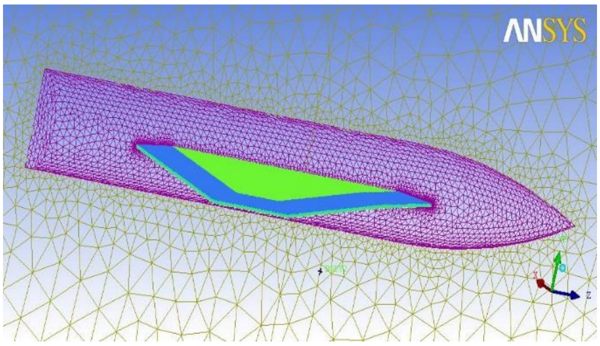

Fig 7: Meshed model of Double delta wing body without domain

5. RESULTS AND DISCUSSION

The model was analysed using ANSYS FLUENT package and the lift and drag coefficients for both the wing body configurations over a range of low angles of attack that is from 0° to 15° are calculated.

The results are tabulated are as follows:

Table 2: Lift and drag coefficients for cropped and Double delta wing body

Angle of attack (AOA) In degrees (°)	**Cropped Delta Wing**		**Double Delta Wing**	
	Lift coefficient (Cl)	Drag coefficient (Cd)	Lift coefficient (Cl)	Drag coefficient (Cd)
0	0	0.05	0	0.04
3	0.125	0.05	0.150	0.03
6	0.260	0.06	0.280	0.03
9	0.390	0.08	0.430	0.05
12	0.520	0.12	0.560	0.08
15	0.650	0.18	0.70	0.12

5.1 CROPPED DELTA WING BODY

A. Lift curve

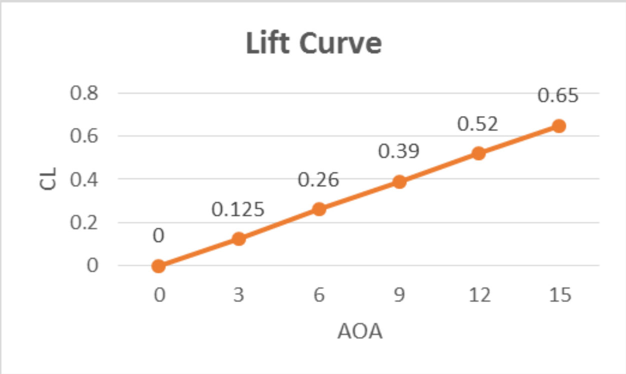

Fig 8: Lift Curve for Cropped Delta Wing

From the above Figure 8 of the cropped delta wing we can observe that the C_L Increases with the increase of Angle of attack. The Lift Coefficient at 0° AOA is 0 and it gradually increase as we increase the AOA at 15° AOA the C_L is 0.65

B. Drag curve

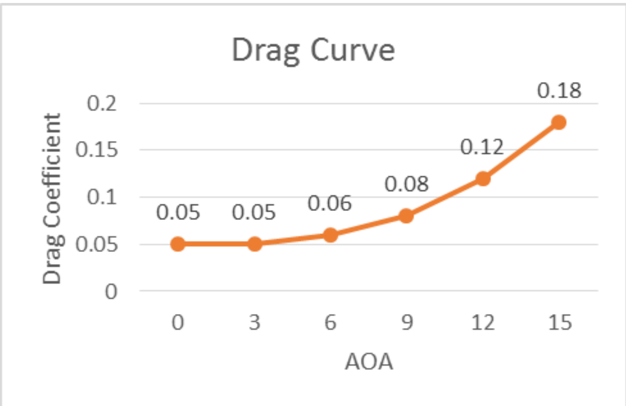

Fig 9: Drag Curve for Cropped Delta Wing

From the above Figure 9 of the cropped delta wing we can observe that the C_D Increases with the increase of Angle of attack. The Drag Coefficient at 0° AOA is 0.05 and it slightly increasing up to 10° and sudden rise from there as we increase the AOA of the cropped wing body and at 15° AOA the C_L is 0.18

C. Drag polar curve

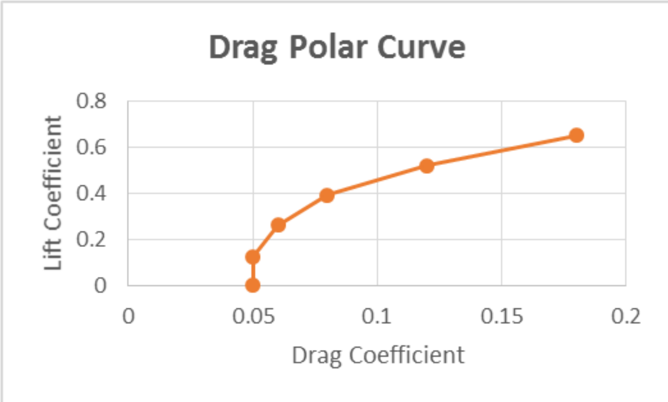

Fig 10: Drag polar Curve for Cropped Delta Wing

From the above Figure 10 you can observe the Comparison of Lift and Drag Coefficient as the C_L increases the C_D increases slights until 9° AOA and then it is witnessed that the C_D rapidly increases as the C_L Increases.

5.2 DOUBLE DELTA WING BODY

A. Lift curve

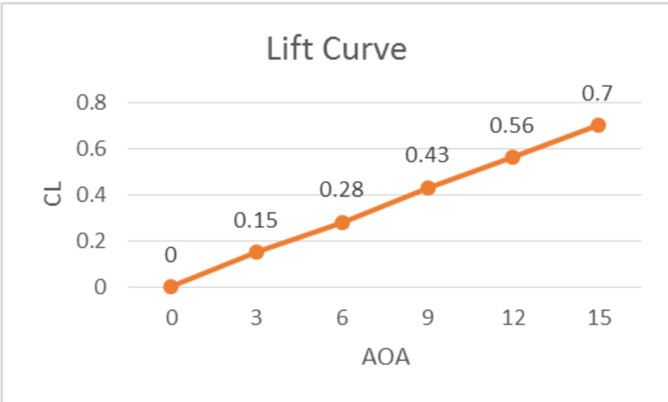

Fig 11: Lift Curve for Double Delta Wing

From the above Figure 11 of the cropped delta wing we can observe that the C_L Increases with the increase of Angle of attack. The Lift Coefficient at 0° AOA is 0 and it gradually increase as we increase the AOA at 15° AOA the C_L is 0.70

B. Drag curve

From the Below Figure 12 of the cropped delta wing we can observe that the C_D Increases with the increase of Angle of attack. The Drag Coefficient at 0° AOA is 0.04 and it slightly increasing up to 6° and sudden rise from there as we increase the AOA of the cropped wing body and at 15° AOA the C_L is 0.12

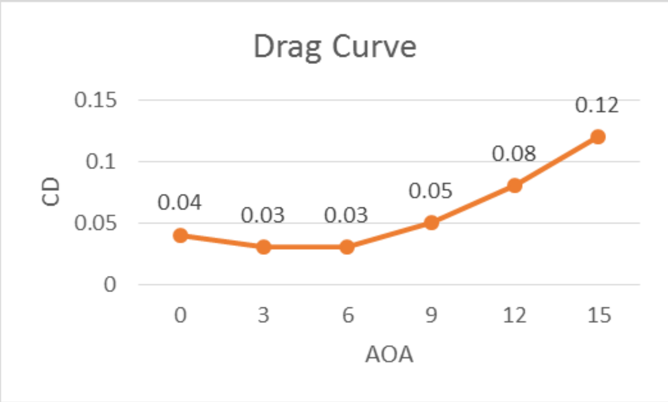

Fig 12: Drag Curve for Double Delta Wing

C. Drag polar curve

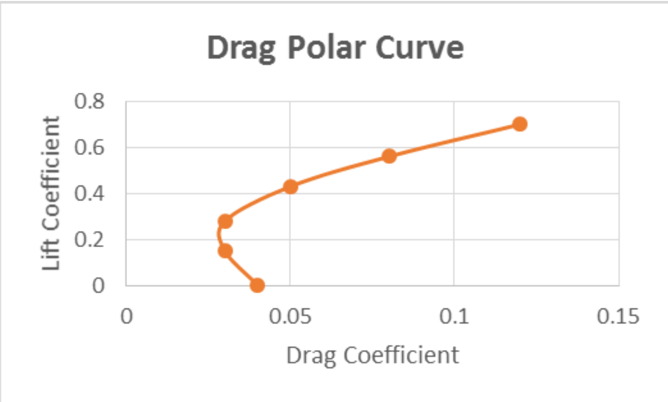

Fig 13: Drag polar Curve for Double Delta Wing

From the above Figure 13 you can observe the Comparison of Lift and Drag Coefficient as the C_L increases the C_D increases slights until 9° AOA and then it is witnessed that the C_D rapidly increases as the C_L Increases and observed to be similar rise of C_D as of cropped delta wing .

5.3 Comparison of lift curve of both the wing body configurations

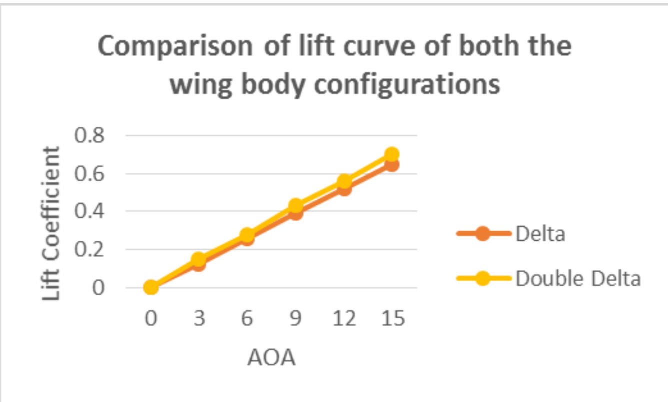

Fig 14: Lift Curve for both Delta Wing Bodies

As from the Figure 14 it can be observed that the double delta wing body is more efficient in producing Lift Co-efficient and is observed that it is achieving more CL compared to Cropped Delta wing. The maximum CL at 15° AOA for cropped delta wing is 0.65 which is less as the CL for Double Delta wing is 0.70

5.4 Comparison of drag curve for both the wing body configurations

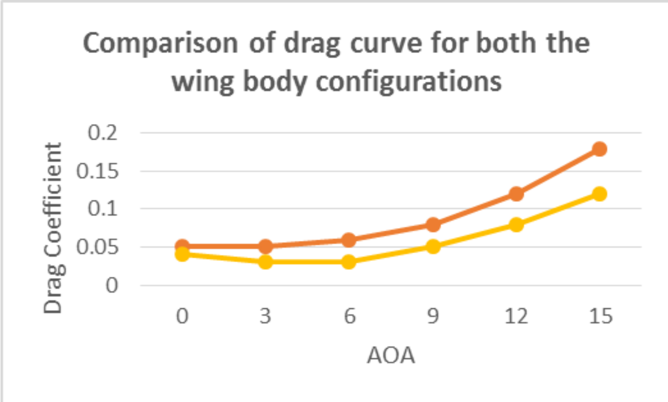

Fig 15: Drag Curve for both Delta Wing bodies

From the above Figure 15 it is seen that the Drag coefficient is less for Double delta wing compared to cropped delta wing the C_D for Cropped delta wing at 15° AOA is 0.18 which is high compared to double delta wing as at 15° AOA the C_D is 0.12

5.5 Comparison of drag polar for both the wing body configurations

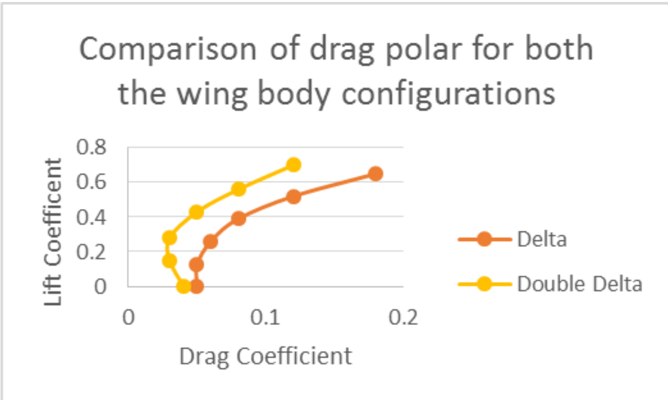

Fig 16: Drag Polar Curve for both Delta Wing Bodies

The above Figure 16 is the comparison of drag polar curve for both wing bodies where C_L v/s C_D is compared and plotted.

In the present study, we have compared the cropped delta wing with the double delta wing. Computational analysis is carried out on both the wing to check the performance characteristics. The analysis is carried out on different angle of attacks from 0° to 15° with the same boundary conditions as per validation. It is observed that the double delta wing generates more lift compared to delta wing and hence decrease in drag.

6. CONCLUSION

In the present study we have compared the cropped delta wing with sweep angle of 60° and double delta wing with a sweep of 55°/60° having a bevelled leading edge are modelled and simulated at Mach number 0.4 and at a Reynolds number (Re) of $2.7x10^4$. From the results obtained we can conclude that double delta wing body is more efficient in producing lift than a cropped one since the lift curve slope of double delta wing body is greater than a cropped delta wing body. As well as lift to drag ratio of double delta is 9.3 which is more than a cropped delta which has lift to drag ratio of 6.6.Therefore double delta wing body configuration is more effective than a cropped delta wing.
The Lift Coefficient for the DDW at 15° AOA is 0.70 which is high compared to DW which has 0.65 at the same. Even there is a huge difference in Drag Coefficient between DW and DDW which is 0.18 and 0.12 respectively. Which again conclude that as the AOA increases the performance is more for the DDW and it is a great challenge to simultaneously measure the data. Therefore, a verification experiment is favourable

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