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CFD Analysis Of Delta Wing Body Configurations At Lower Angle Of Attack

Research Article

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Abstract

The delta wing is a wing plan form in the form of a triangle. It is named for its similarity in shape to the Greek letter delta (Δ). The first practical uses of delta wing came in the form of so-called "tailless delta", i.e. without the horizontal tail plane. As the angle of attack increases, the leading edge of the wing generates a vortex which energizes the flow, giving the delta a very high stall angle.Pure delta-wings fell out of favour 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 modern light weight fighter that can cruise supersonically, maneuver transonically and has a post stall capability requires additional highly swept area ahead of the main wing called strake or leading edge extension (LEX) which lead to some of the variations in delta wing such as tailed 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 deltawing body configuration at low angles of attack (α) from 0 to 15 degrees with an increment of step 3. Delta wing with sweep angle of 60 degrees and double delta wing with a sweep of 55/60 degrees having a beveled leading edge are modeled and simulated at Mach number 0.4 and at a Reynolds number (Re) of 2.7x104]. 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.

Keywords: C: Wing Chord; S: Wing Reference; b: Wing Span; λ: Taper Ratio; - A: Aspect Ratio.

Introduction

The delta wing body configuration consists of a delta wing along with the fuselage so called as body.Pure delta-wingsfell out of favour somewhat due to their undesirablecharacteristics, 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:adds a conventional tailplane (with horizontal tail surfaces), to improve handling (MiG-21).
• Cropped delta: tip is cut off. This helps avoid tip drag at high angles of attack (F-16).
• Compound delta, double delta or cranked arrow: the inner part of the wing has a very high sweepback, while the outer part has less sweepback, to create the high-lift vortex in a more controlled fashion, reduce the drag and thereby allow for landing the delta at acceptably slow speed[4]. (Saab Draken fighter and High Speed Civil Transport).
• Ogee delta (ogival delta): with a smooth 'ogee' curve joining the two parts rather than an angle.

Scope

The present project is based on the computational analysis of flow over delta wing body configurations (cropped delta and double delta) at lower angle of attack ofa typical fighter aircraft.

Design and analysis of wing body configuration is important

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for overall aerodynamic performance of an aircraft [3]. 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.

The analysis of steady flow is done for a semi half span of wing body configuration at sea level and at Reynolds number of 2x105. The analysis is done for five low angles of attack i.e , from 3 to 15 degrees with a step increment of three at a subsonic mach number of 0.5 . Also the scope of this project is to get hands on experience in using the following software tools:

• Modeling of the geometry using CATIA V5R20.
• Meshing of the geometry using ANSYS ICEM CFD.
• Analysis of the flow using ANSYS FLUENT.

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.

Problem Formulation

As we have studied earlier and also seen in the literature that 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.

In this present work we have made an effort to study the flow characteristics over the double delta having sweep of [2] 55/60 degrees2 where there is less difference between the sweep and the strake angle and the cropped delta wing having a sweep angle of 60 degrees with a beveled leading edge are modeled and simulated at Mach number 0.4 and at a Reynolds number (Re) of 2x105. 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.

Boundary Conditions

There are a number of common boundary types.

INLET

Inflow: Transported variables specified on the boundary, either by a predefined profile by doing an initial 1-d, fully-developed-flow calculation.

Stagnation (or reservoir): Total pressure and total temperature (in compressible flow) or total head (in incompressible flow) fixed. usually inflow condition for compressible flow.

OUTLET

Outflow: Zero normal gradient for all variables.
Pressure: As for outflow, except fixed value of pressure; usual outlet condition in compressible flow if the exit is subsonic.

Radiation (or convection): Prevent wave-like motions from reflecting at outflow boundaries by solving a simplified first-order wave equation with outward-directed wave velocity.

WALL:

Non-slip wall: The default case for solid boundaries (zero velocity relative to wall stress computed by viscous-stress or wall-function expressions).

Slip wall: Only the velocity component normal to the wall vanishes. Used if it is not necessary to resolve a thin boundary layer on an unimportant wall boundary.

Geometric Modelling

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

CASE 1: CROPPED DELTA WING

• Planform : cropped delta
• Aspect ratio : 4
• Leading edge sweep : 60 deg
• Trailing edge sweep : 0 deg
• Taper ratio : 0.18
• Twist : 0 deg
• Root chord : 153
• Semi span of model : 75.256
(All dimensions are in mm)

CASE 2: DOUBLE DELTA WING BODY

• Planform : double delta
• Aspect ratio : 3.8
• Leading edge sweep : 60 deg
• Strake angle : 55 deg
• Trailing edge sweep : 0 deg
• Taper ratio : 0.203
• Twist : 0 deg
• Root chord : 39
• Semi span of model : 75.26
(All dimensions are in mm)

Mesh Generation

The model made in CATIA is imported to ANSYS ICEM CFD in ".stl" 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 are 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

Figure 1. Double delta wing body (lower surface).

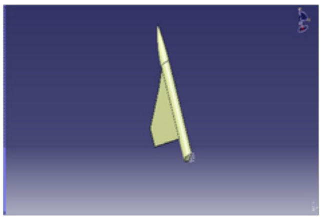


Figure 2. Cropped delta wing body (upper surface).

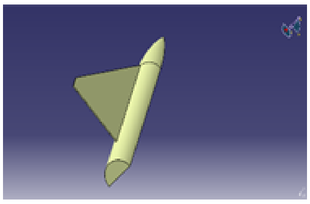


Figure 3. Cropped delta wing body (lower surface).

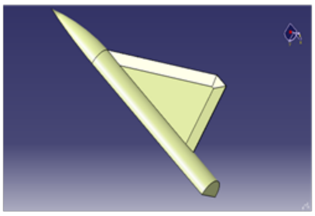


Figure 4. Segmented model with domain without cap.

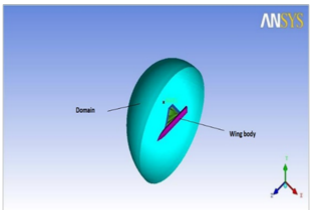


Figure 5. Segmented domain with cap.

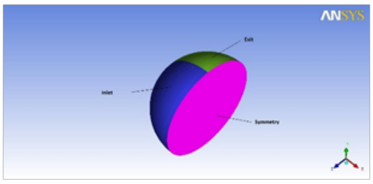


Figure 6. Meshed model of double delta wing body with domain.

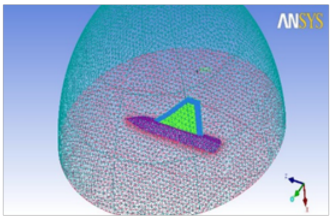
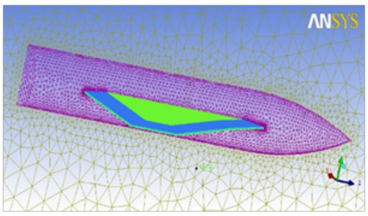


Figure 7. Meshed model of double delta wing body with domain.



and quality mesh.

• The curves are extracted from the surface and extra curves are deleted.

• 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.

Results And Discussion

Cropped Delta Wing Body

Case 2: Double Delta Wing Body

• From the graph of lift curve 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.

• Lift to drag ratio of Cropped Delta wing body is

• Lift to drag ratio of Double Delta wing body is

• 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.

Figure 8.

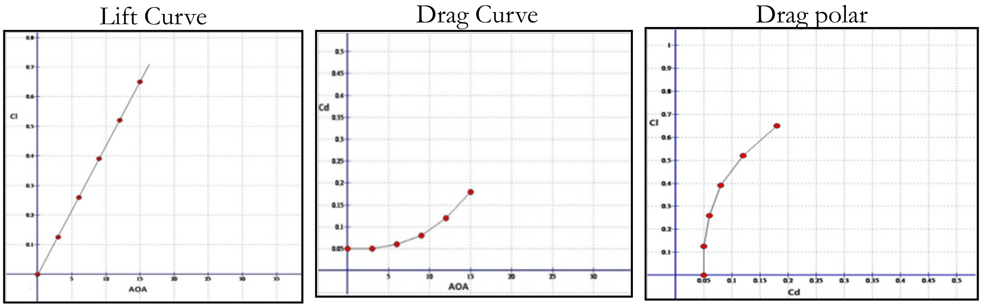


Figure 9.

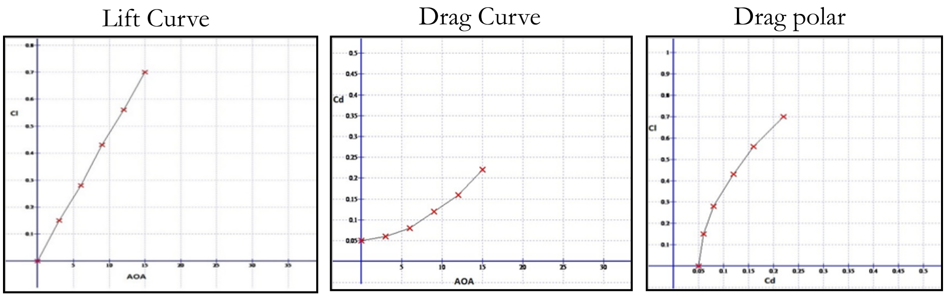


Figure 10. Comparison of lift curve of both the wing body configurations.

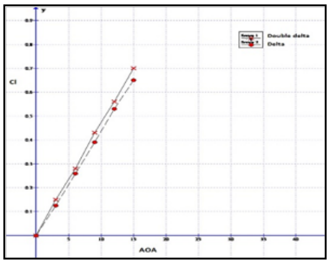


Figure 11. Comparison of drag curve for both the wing body configurations.

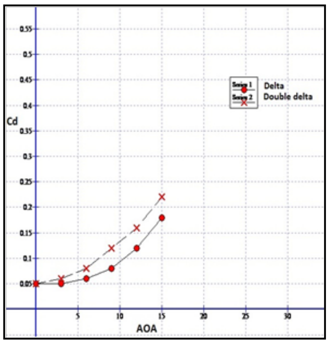
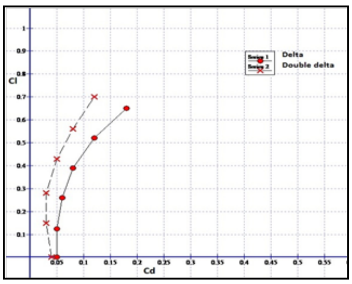


Figure 12. Comparison of drag polar for both the wing body configurations.



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