Delta wing Aerodynamics

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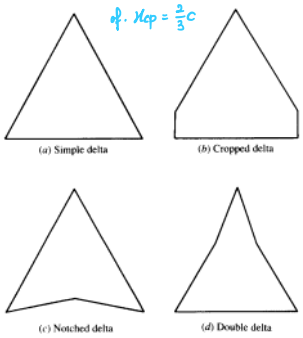
For the glory of God

Introduction

- Supersonic flow is totally different from subsonic flow in all aspects physically and mathematically.
- Supersonic airplanes usually have highly swept wings.
  - ↳ A special case of swept wing is with a triangular planform, namely Delta wings. (It is subject to reduce a wave drag)
- Delta wings are used on many different types of high speed airplanes around the world.



cf. $x_{cp} = \frac{2}{3}c$

Here,

(a) Convair F-102A

: The first operational Jet airplane in the US to be designed with a delta wing.

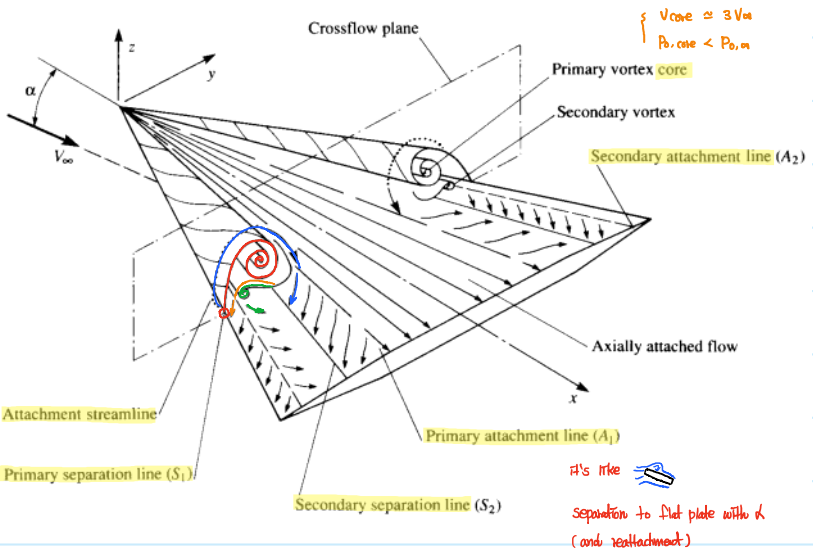
(d) Space Shuttle

: Indeed, it is a hypersonic airplane.

- Then, why are we discussing this topic of the low-speed and incompressible flow over finite wings?
  - ⇒ Obviously, all high-speed aircraft should fly at low speed for takeoff and landing. Moreover, they sometimes fly at subsonic.
- For this reason, the low-speed aerodynamics characteristics of delta wings are of great importance.

Delta wing Aerodynamics

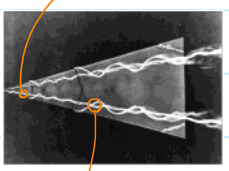
- The subsonic flow pattern over the top of a delta wing at angle of attack is sketched as follows.



$V_{core} \simeq 3V_\infty$
$P_{0,core} < P_{0,\infty}$

It's like separation to flat plate with α (and reattachment)

They grow in size as they move downstream



The leading edge vortices are positioned above.

- The dominant aspect of this flow are the two vortex patterns that occur in the vicinity of the highly swept leading edges.
- These vortex patterns are created by the following mechanism;

1) The pressure on the bottom is higher than the pressure on the top due to the angle of attack.

2) The flow on the bottom surface in the vicinity of L.E. tries to curl around the L.E. from the bottom to the top.

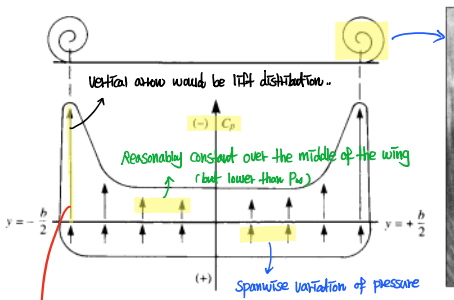
3) Since the L.E. is sharp, the flow will separate along its entire length.

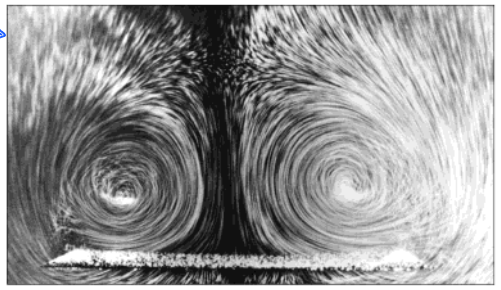
4) This separated flow curls into a primary vortex which exists above the wing just inboard of each leading edge.

5) And then it reattaches along the primary attachment line (line A_1)

The primary vortex is contained within this loop 1) ~ 5)

- A secondary vortex is formed underneath the primary vortex with its own separation and reattachment lines.
- Since the leading edge vortices (positioned above and somewhat inboard) are strong, it turns out;
  - Being a source of high energy → Relatively high-velocity flow → local static pressure around the vortices is small





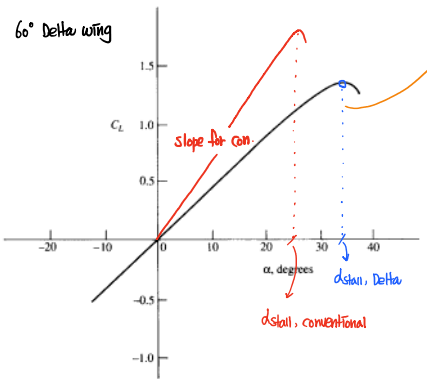
Hence, the surface pressure on the top surface of the delta wing is reduced near the leading edge.

⇒ This phenomena so-called suction effect of the leading edge vortices enhances the lift (Vortex lift)

∴ For this reason,

the lift coefficient curve for a delta wing exhibits an increase in C_L for values of α at which conventional wing planforms would be stalled. (But the lift slope is small)

Basically, Delta wing has low thickness. So less lift but delayed stall angle.



You may understand why α is large - because the lift slope is small - and hence the α must be large enough to generate the high values of C_L required for low-speed flight.

It increases the drag at the same time

∴ L/D for a delta wing is not so high.

- Therefore, the aerodynamic effect of these vortices is not necessarily advantageous.

Application

- We have treated the case of a sharp leading edge; such sharp edges cause the flow to separate at L.E.
- On the other hand, if the L.E. radius is large, the flow separation will be minimized.

↳ In turn, the drag penalty will not be presented.

- However, we mentioned that the delta-wing planform with sharp leading edge is advantageous for supersonic flight. This advantage will be negated if the L.E is rounded.

(A singular exception is the design of the Space Shuttle)

↳ It prefer to have a well-rounded L.E.