

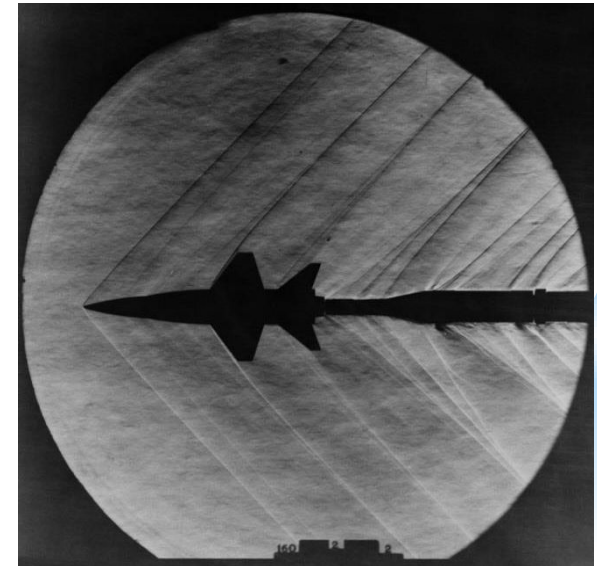
\* SWEET, Diamond And

Delta Wings

Sangram Samal

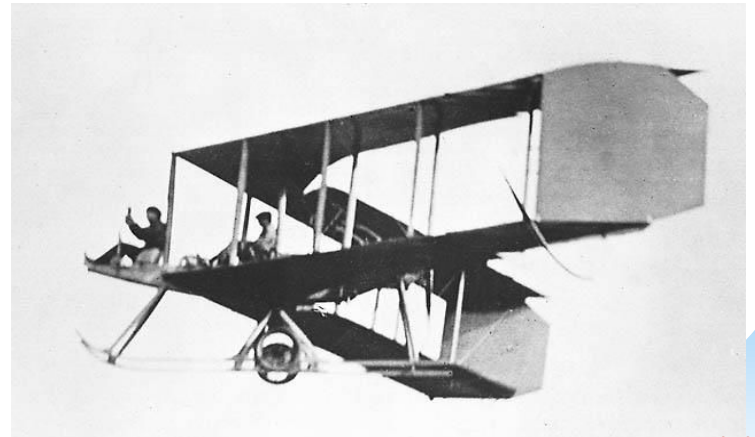
When aircraft enters the transonic speeds just below the speed of sound, an effect known as wave drag starts.

- \* Near the speed of sound oblique shock wave is generated.
- \* Shock waves require energy to form.
- \* The energy reduces airplanes power.



# INTRODUCTION\*

- \* Anglo-Irish engineer John William Dunne was experimenting along similar lines, obsessed with achieving innate stability in flight. He was able to successfully employ severely swept wings in his tailless aircraft as a means of creating positive longitudinal static stability.<sup>[2]</sup> For a low-speed aircraft, swept wings are useful to avoid problems with the
  - \* 1-center of gravity, to move the wing spar into a more convenient location,
  - \* 2- to improve the sideways view from the pilot's position



Early History\*

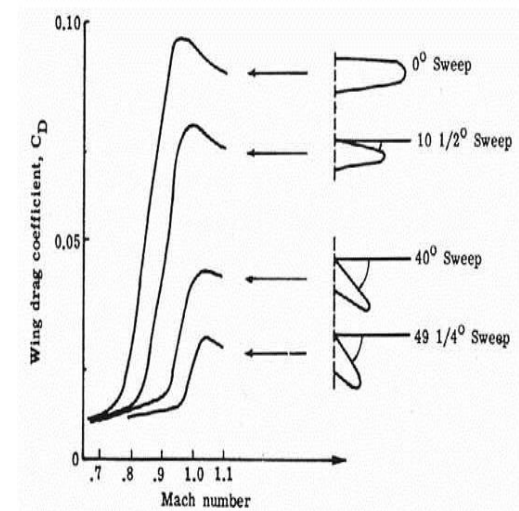
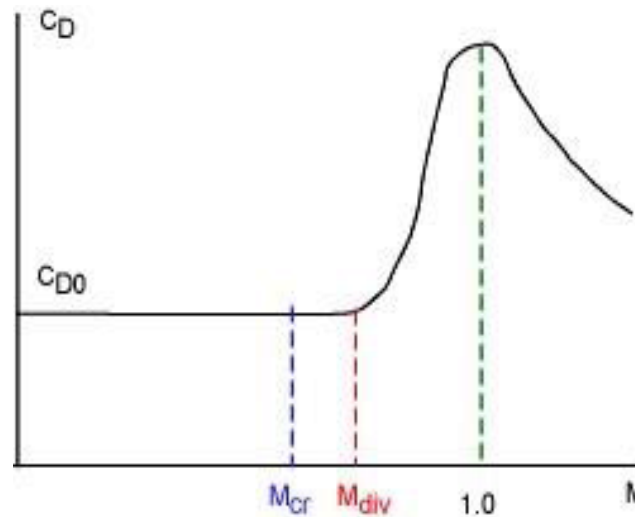
# Sweep Theory\*



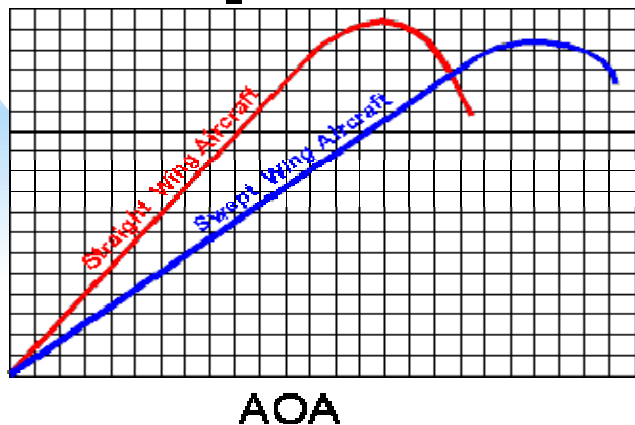
- \* One of the simplest and best explanations of how the swept wing works was offered by [Robert T. Jones](#): "Suppose a cylindrical wing (constant chord, incidence, etc.) is placed in an airstream at an angle of yaw - ie., it is swept back. Now, even if the local speed of the air on the upper surface of the wing becomes supersonic, a shock wave cannot form there because it would have to be a sweptback shock - swept at the same angle as the wing - ie., it would be an oblique shock. Such an oblique shock cannot form until the velocity component normal to it becomes supersonic."

# DRAG AND MACH NUMBER\*

$M_{crit}$  : 'Mcrit' in aerodynamics, is in fact the 'critical Mach Number' of an aircraft. It is the lowest Mach number at which the airflow over some point on the aircraft reaches the speed of sound. A Mach number of 1.0 indicates an airspeed equals to the speed of sound in the air



## $C_L$ vs AOA



The drag divergence Mach number (not to be confused with [critical Mach number](#)) is the [Mach number](#) at which the [aerodynamic drag](#) on an [airfoil](#) or [airframe](#) begins to increase rapidly as the Mach number continues to increase.<sup>[1]</sup> This increase can cause the [drag coefficient](#) to rise to more than ten times its [low speed](#) value.

# Different type of Sweep\*

1. Sweep back
2. Sweep forward
3. Variable sweep

forward sweep \*



Variant of \*

Design features

# Forward swept wing\*

- \* Allowing more space in generally cramped corporate jet cabins
- \* Relatively expensive.
- \* Highly maneuverable at transonic speeds



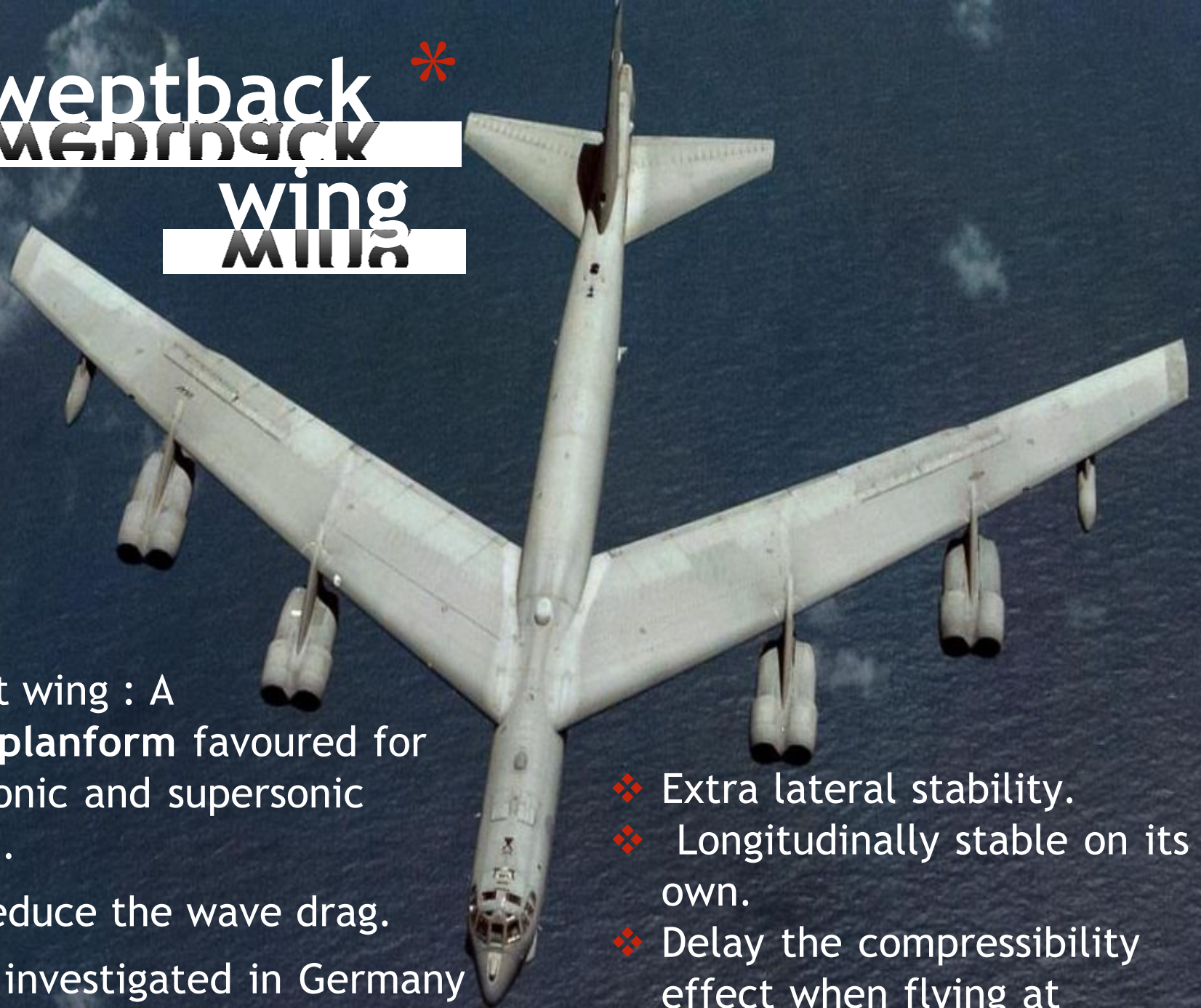
# Sweptback \*

## 2M6H7H9CK

## wing MIIH

- \* Swept wing : A wing planform favoured for transonic and supersonic flying.
- \* To reduce the wave drag.
- \* first investigated in Germany from 1935 onwards

- ❖ Extra lateral stability.
- ❖ Longitudinally stable on its own.
- ❖ Delay the compressibility effect when flying at transonic speed

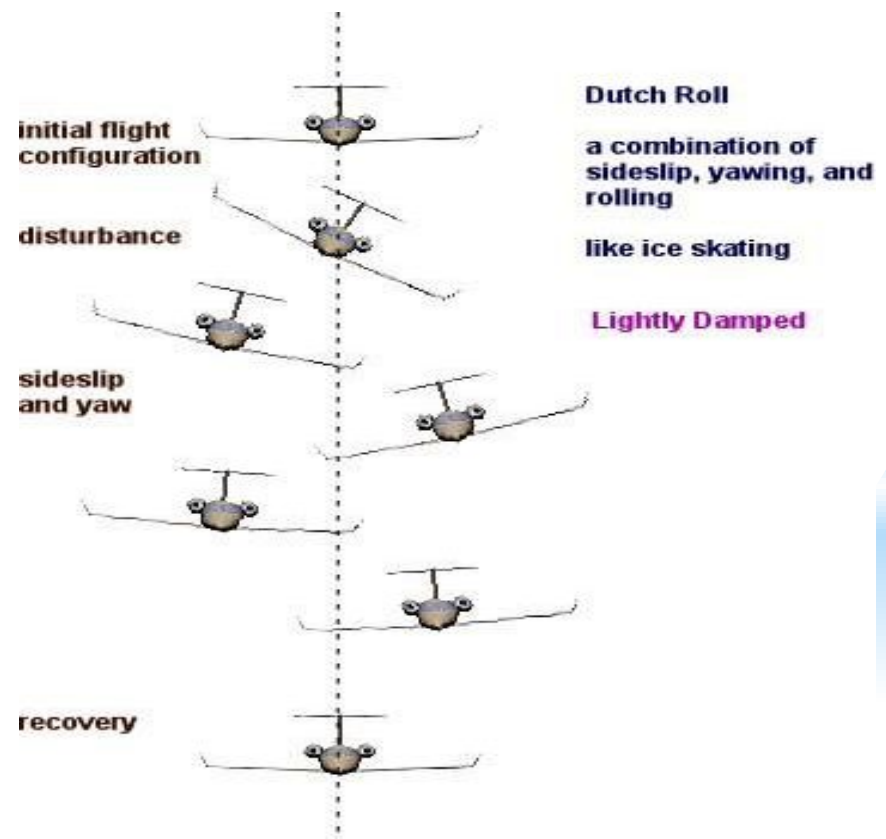
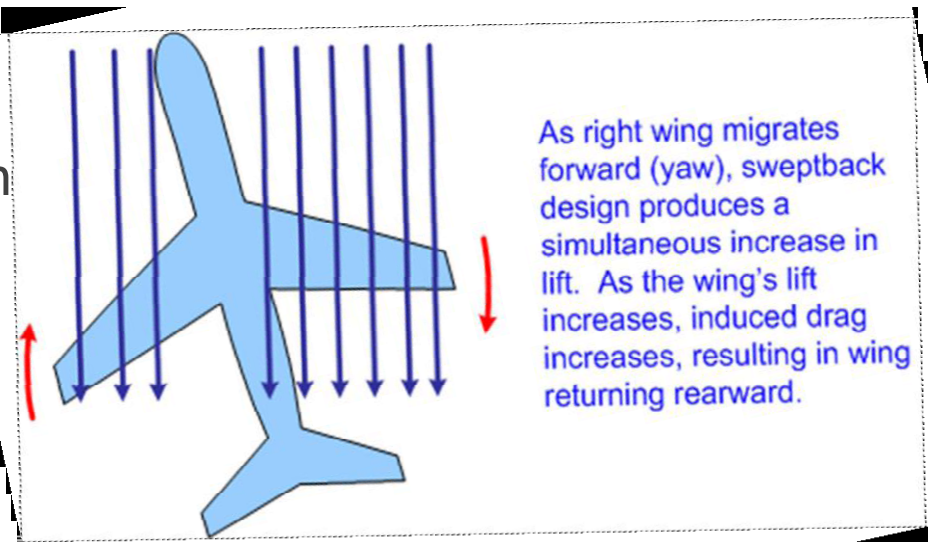


# Disadvantages\*

- \*When a swept wing travels at high speed, the airflow has little time to react and simply flows over the wing almost straight from front to back. At lower speeds the air *does* have time to react, and is pushed spanwise by the angled leading edge, towards the wing tip. At the wing root, by the fuselage, this has little noticeable effect, but as one moves towards the wingtip the airflow is pushed spanwise not only by the leading edge, but the spanwise moving air beside it. At the tip the airflow is moving along the wing instead of over it, a problem known as *spanwise flow*.

- ❖ The lift from a wing is generated by the airflow over it from front to rear. With increasing span-wise flow the boundary layers on the surface of the wing have longer to travel, and so are thicker and more susceptible to transition to turbulence or flow separation, also the effective aspect ratio of the wing is less and so air "leaks" around the wing tips reducing their effectiveness. The spanwise flow on swept wings produces airflow that moves the stagnation point on the leading edge of any individual wing segment further beneath the leading edge, increasing effective angle of attack of wing segments relative to its neighbouring forward segment. The result is that wing segments farther towards the rear operate at increasingly higher angles of attack promoting early stall of those segments. **This promotes tip stall on back swept wings**, as the tips are most rearward, while **delaying tip stall for forward swept wings**, where the tips are forward. With both forward and back swept wings, the rear of the wing will stall first. This creates a nose-up pressure on the aircraft. If this is not corrected by the pilot it causes the plane to pitch up, leading to more of the wing stalling, leading to more pitch up, and so on. This problem came to be known as the *Sabre dance* in reference to the number of North American F-100 Super Sabres that crashed on landing as a result.

\* The swept wing also has several more problems. One is that for any given length of wing, the actual span from tip-to-tip is **shorter than the same wing that is not swept**. Low speed drag is strongly correlated with the aspect ratio, the span compared to chord, so a swept wing always has more drag at lower speeds. Another concern is the **torque applied by the wing to the fuselage**, as much of the wing's lift lies behind the point where the wing root connects to the plane. Finally, while it is fairly easy to run the main spars of the wing right through the fuselage in a straight wing design to use a single continuous piece of metal, this is not possible on the swept wing because the spars will meet at an angle.





## \* Variable-sweep wing

- \* Also known as swing wing.
- \* That may be swept back and then returned to its original position during flight.

# \* Advantages

\* Aeroelastically enhanced maneuverability

\* Smaller basic lift distribution

\* Increased trailing edge sweep for given structural sweep - lower  $C_{Dc}$

\* Unobstructed cabin

\* Easy gear placement

\* Good for turboprop placement

\* Subsonic stability and supersonic abilities



- \* Aeroelastic divergence or penalty to avoid it
- \* Lower  $C_{n\beta}$  (yaw stability)
- \* Bad for winglets
- \* Stall location (more difficult)
- \* Reduced pitch stability due to additional lift and fuse interference

**Disadvantages\***

\*The **delta wing** is a wing planform in the form of a triangle. It is named for its similarity in shape to the Greek uppercase letter delta ( $\Delta$ ).



\* Delta wings  
REIRA MILITARY



# Early History\*

## \* Delta wing

- \* The first practical uses of delta wing came in the form of so-called "tailless delta", i.e. without the horizontal [tailplane](#). In fact the designs were at the same time also the first [flying wings](#). It could be argued if 1924 [Cheranovsky](#) designs, having one-of-a-kind parabolic planform,<sup>[5]</sup> fit the category of delta wings. Nevertheless, a triangular wing was pioneered especially by [Alexander Lippisch](#) in Germany. He was first to fly tailless delta aircraft in 1931,<sup>[6][7]</sup> followed by four improved designs. None of these was easy in handling at slow speeds, and none saw widespread service.<sup>[8][9]</sup> During the war Lippisch studied a number of [ramjet](#) powered (sometimes coal-fueled) delta-wing [interceptor aircraft](#), one progressing as far as a glider prototype.<sup>[10]</sup> Another pioneering design was the 1934 delta-wing Sigma 4 Interceptor, designed by [Aleksandr Moskalyev](#) in the Soviet Union.<sup>[citation needed]</sup>
- \* The tail-less delta became a favored design for high-speed use, and was used almost to the exclusion of other designs by [Convair](#) and by [Dassault Aviation](#) in France, notably with the popular [Dassault Mirage III](#). Convair's [F-102](#) was the first fighter with a tailless delta wing in service with any [air force](#) anywhere in the world.<sup>[citation needed]</sup>
- \* Meanwhile, the British also developed aircraft based on the data from Lippisch, notably the [Avro Vulcan](#) strategic bomber and the [Gloster Javelin](#) fighter. The Javelin incorporated a tailplane in order to rectify some of the perceived weaknesses of the pure delta, to improve low-speed handling and high-speed manoeuvrability and to allow a greater [center of gravity](#) range.<sup>[11]</sup>
- \* The tailed delta configuration was again adopted by the [TsAGI](#) (Central Aero and Hydrodynamic Institute, [Moscow](#)), to take advantage of both high angle-of-attack flying capability and high speeds. It was used in the [MiG-21](#) (Fishbed) and [Sukhoi Su-9/Su-11/15](#) fighters, built by the tens of thousands in several different communist countries.<sup>[citation needed]</sup>
- \* More recently, [Saab AB](#) used a close-coupled damped [canard](#) foreplane<sup>[12]</sup> in front of the main wing of the [Viggen](#) fighter. The close coupling actively modifies the airflow over the wing, most notably during flight at high angles of attack. In contrast to the classic tail-mounted elevators, the canards add to the total lift, enabling the execution of extreme maneuvers, improving low-speed handling and lowering the landing speed.

# \* Advantages & Disadvantages

- \* The primary advantage of the delta wing is that, with a large enough angle of rearward sweep, the wing's leading edge will not contact the **shock wave** boundary formed at the nose of the fuselage as the speed of the aircraft approaches and exceeds **transonic** to **supersonic** speed. The rearward sweep angle vastly lowers the airspeed normal to the leading edge of the wing, thereby allowing the aircraft to fly at high **subsonic**, transonic, or supersonic speed, while the over wing speed of the lifting air is kept to less than the speed of sound. The delta plan form gives the largest total wing area (generating useful lift) for the wing shape, with very low wing per-unit loading, **permitting high manoeuvrability in the airframe**. As the delta's platform carries across the entire aircraft, **it can be built much more strongly than a swept wing, where the spar meets the fuselage far in front of the centre of gravity**. Generally a delta will be stronger than a similar swept wing, as well as **having much more internal volume for fuel and other storage**.
- \* Another advantage is that 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**. A normal wing built for high speed use is typically dangerous at low speeds, but in this regime the delta changes over to a mode of lift based on the vortex it generates. Additional advantages of the delta wing **are simplicity of manufacture**, strength, and substantial interior volume for fuel or other equipment. Because the delta wing is simple, it can be made very robust (even if it is quite thin), and it is easy and relatively inexpensive to build - a substantial factor in the success of the MiG-21 and Mirage aircraft.
- \* The disadvantages, especially marked in the older tailless delta designs, are a **loss of total available lift** caused by turning up the wing trailing edge or the control surfaces (as required to achieve a sufficient stability) and the **high induced drag of this low-aspect ratio type of wing**. This causes delta-winged aircraft to **'bleed off' energy very rapidly in turns**, a disadvantage in **aerial manoeuvre combat and dogfighting**. It also causes a reduction in lift at takeoff and landing until the correct angle of attack is achieved, this means that the rear undercarriage must be more strongly built than with a conventional wing.

# Diamond Wings\*



\*The trapezoidal or diamond wing is a high-performance wing configuration. It is a short (low aspect ratio) tapered wing having little or no overall sweep, such that the leading edge sweeps back and the trailing edge sweeps forward. The trapezoidal design allows for a thin wing with low drag at high speeds, while maintaining high strength and stiffness. To date, all major aircraft to use this design have come from the United States.

# \* Where to use

- \* A diamond wing shape is chosen if you want to have the supersonic drag benefits of a delta, but without the low-speed problems and the excessive AoA of a delta.
- \* This quote was taken from the October 1998 issue of Code One magazine:

"The structural engineers wanted a diamond wing because it provides a larger root chord, which carries bending moments better," Hardy notes. "The aerodynamicists wanted a trapezoidal wing because it provides more aspect ratio, which is good for aerodynamics. Heppe, the president of Lockheed California Company, made the final decision, and he was right. The aerodynamics were not all that different, but the **structure and weights were significantly better**. So we went to a diamond shape. The big root chord, though, moved the tails back. Eventually we even had to notch the wing for the front of the tails. If the tails moved farther back, they would fall off the airplane."

- \* <http://forum.keypublishing.com>
- \* <http://en.wikipedia.org/>
- \* <http://www.slideshare.net/>
- \* <http://flightclub.blogspot.com/>
- \* <http://www.flymagazine.net/>
- \* <http://aero.stanford.edu>
- \* <http://deltafighterwing.com/>
- \* <http://www.sweepwings.com/>

## \* References