Chapter 1

THE STALL

The stall of an aircraft, at whatever the speed, should be the result of a planned and skillfully executed flight-control input by the pilot. A stall is not something that should generate fear, loss of control, or an accident. Rather it is an aerodynamic phenomenon that should be understood, and practiced in training, by a proficient pilot.

Many acrobatic maneuvers include some form of stall. For example, a snap roll from level flight is a high-speed stall, with so much energy along the flight path that the nose remains near the horizon—a horizontal spin. The Falling Leaf is a series of near spins. Precision spins include several autorotative turns with recovery on a specific point. Then there are the whip stall, hammerhead stall, or tail slide, and any number of other aerial thrillers, each derived from the controlled and skilled use of aerodynamic stall.

Practically speaking, our piloting skills are directed toward avoiding stalls. After all, the shudder of a stall signals the sudden decrease in aerodynamic lift, which is the lifeblood of flight. So our first goal in this dissection of the stall/spin phenomenon is to thoroughly understand the factors involved when an aircraft stalls.

Elements of Lift

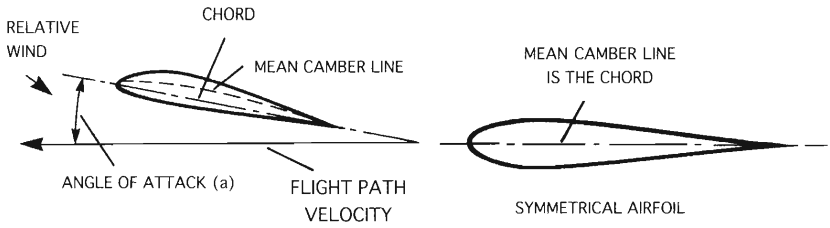
A wing generates lift as it passes through the air with an angle of attack (AOA) greater than the airfoil's zero-lift angle. With a symmetrical airfoil, lift is generated anytime the wing's chord line (straight line connecting the leading and trailing edges of the airfoil) is at an angle above the relative wind. At zero angle of attack, lift will be zero.

A wing with a positive camber, such as found on most light aircraft, will have a negative angle for zero lift. See Diagrams 1–1 and 1–1A.

The amount of lift generated at a given AOA is a function of airspeed. Greater airspeeds generate greater lift. For a particular airplane, if you increase engine horsepower and/or reduce drag, it will be capable of higher speed or of carrying more weight.

How Lift is Generated

With a positive AOA, the camber (curvature) of an airfoil becomes the bottom half of an imaginary venturi, with the undisturbed airstream (called



"CAMBER" REFERS TO THE CURVATURE OF AN AIRFOIL'S SURFACES.THE AIRFOIL ABOVE HAS POSITIVE CAMBER, BECAUSE THE MEAN CAMBER LINE IS ABOVE THE CHORD.

Diagram 1–1

LIFT CURVES FOR CAMBERED AND SYMMETRICAL AIRFOILS

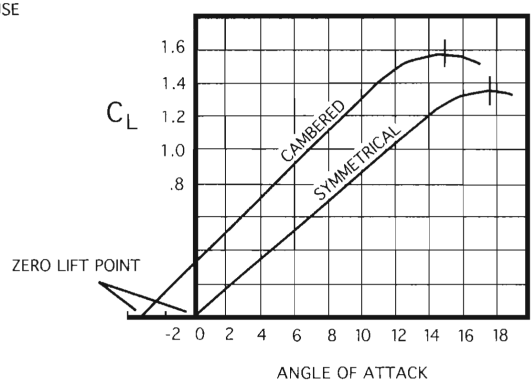
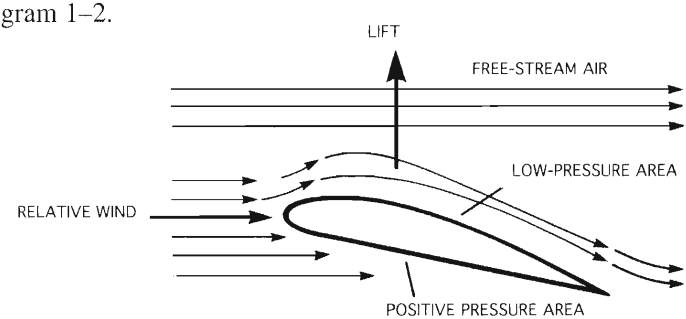


Diagram 1–1A

freestream) above the wing acting as the top half. Because subsonic free-flowing air cannot be compressed by being packed into the throat of a venturi, it accelerates. This in turn causes pressure to drop, creating a low-pressure area on the upper wing (or bottom of the imaginary venturi). See Diagram 1–2.

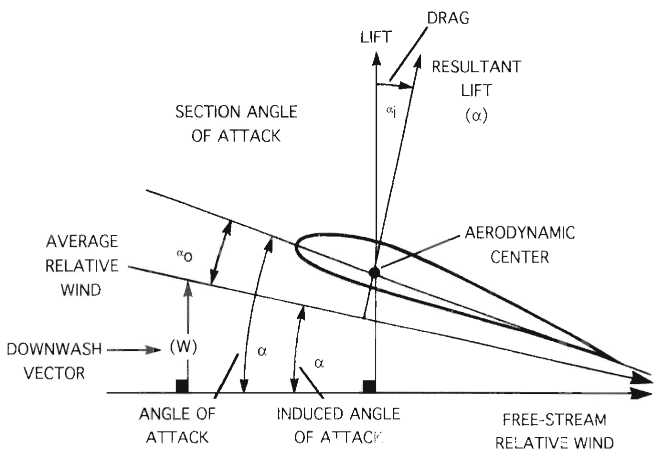


THE GENERATION OF LIFT

Diagram 1–2

Further, due to the wing's positive AOA, air hitting the underwing surface creates positive pressure, or an upward push. At high AOA this pressure will account for about one third of the net lift.

As lift is generated, a downwash is created behind the wing, which causes a downward inclination of the average relative wind. Consequently, to maintain the same lift potential, the AOA must be increased slightly to offset the inclination of the relative wind. Because the resulting lift acts perpendicularly to the average relative wind, and because the relative wind is inclined downward, the lift vector is inclined aft by the same amount. The angle between the average relative wind and the remote free air stream (undisturbed air) is known as *induced angle of attack*. See Diagram 1–3.



DRAG VECTOR DIAGRAM

Diagram 1–3

The downwash vector (W) is reversed and added to the opposite end of the free-stream relative wind vector to simplify the diagram. The average relative wind, which actually affects the wing, is inclined to the free-stream relative wind. This is the induced angle of attack. The force produced by the wing, labeled resultant lift to avoid confusion, is perpendicular to the average relative wind. The actual lift force is that component of the resultant force that is perpendicular to the free-stream relative wind. The component of the resultant force that is parallel to the free-stream relative wind is the induced drag. (Resultant force should not be confused with aerodynamic force. The latter includes parasitic and Induced drag.)

This provides a lifting force that can be split into two components, one that is perpendicular to the remote free airstream ahead of the wing and one that is parallel: a resultant as it were, caused by inclination of the average relative wind and induced AOA. This undesirable parallel force acts to counter engine thrust and is called induced drag. Increasing the angle of attack increases the angle of "tilt," which means that as lift increases so too does induced drag.

Drag

Although there are several types of aerodynamic drag, the pilot is concerned with only two basic types, induced and parasitic.

Induced drag, as discussed previously, predominates at high AOA and low airspeed and is the undesirable result of producing lift. Induced drag **decreases** as airspeed **increases,** in inverse proportion to the square of the airspeed. In other words, the downward deflection of the relative wind diminishes as airspeed increases, which causes AOA to decrease.

Parasitic drag predominates at high speed and consists of a combination of form drag, skin friction, and interference drag. (It is not due to the production of lift but is instead a variable with lift.) Form drag results from the airplane's movement through the air. Skin friction results as air flows around the fuselage, wing, tail, nacelles, gaps in control surfaces and access areas, struts, door handles, etc. Interference occurs, for example, with boundary-layer air between the fuselage and wing root.

The Stall

At normal angles of attack, for example during climb, cruise, and descent, the airflow about a wing follows the top and bottom camber. Airflow over the top surface is smooth until it reaches the trailing edge. At this point the boundary layer separates and a light, turbulent wake develops. See Diagram 1–4. This wake remains essentially unchanged as the wing's AOA is increased up to a certain point. See Diagram 1–5.

Notice in the diagram that, up to AOA of about 12 degrees, boundary-layer separation remains constant. However, if AOA is increased beyond the straight-line portion of the coefficient-of-lift curve, in this case 12 degrees, boundary-layer separation moves forward along the wing's upper surface, decreasing the area that is working to produce lift. Continuing to increase AOA results in an ever smaller increase in lift per degree.

To illustrate, let's say we are in the landing pattern making a normally banked left turn from downwind to base leg. With no greater than one G applied, no boundary-layer separation occurs; AOA is normal.

Then, upon turning final, we discover that a left crosswind is blowing us across the runway centerline. To compensate, we increase our angle of bank and begin pulling back on the stick, which increases our G load, tightening the final turn to keep from overshooting. Our back stick pressure increases

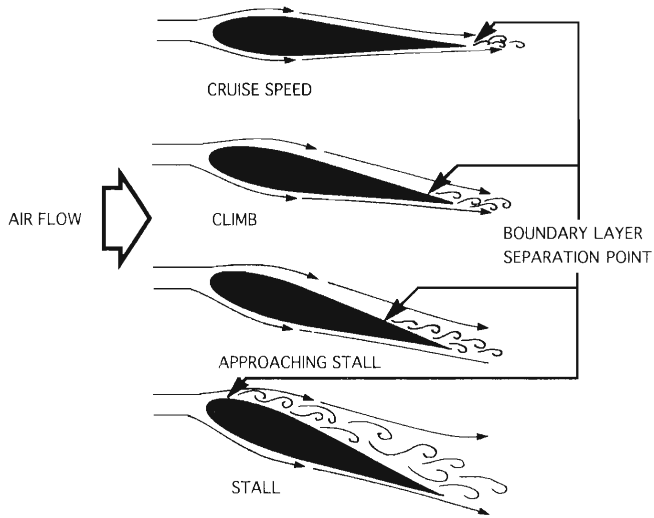
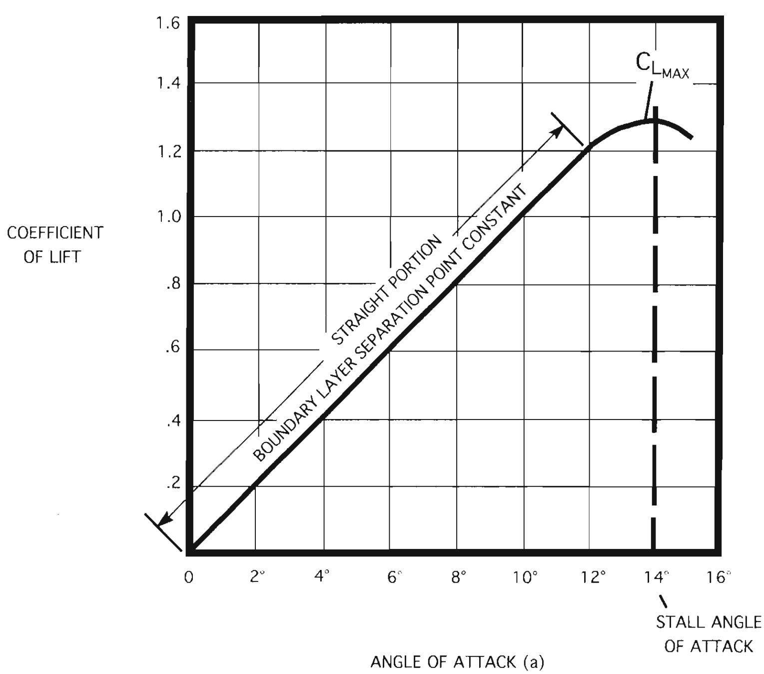


Diagram 1–4



COEFFICIENT OF LIFT vs. ANGLE OF ATTACK

Diagram 1–5