Lift Distribution On Flying Wing Aircraft

By Dr. Reimar Horten

The following contains the essence of what was presented to me by Dr. Horten during my visit to his home in Athos Pampa, Argentina in May 1980. *J. Scott*

After Dr. von Prandtl had published his wing theory in Gottingen in 1918, and thereby established a basis for an understanding of the lift distribution spanwise across the wing, as well as the presence of induced drag, it was found that a flat elliptical plan-form shape gave a uniform air deflection along the entire span, which minimized the induced drag. It was also determined

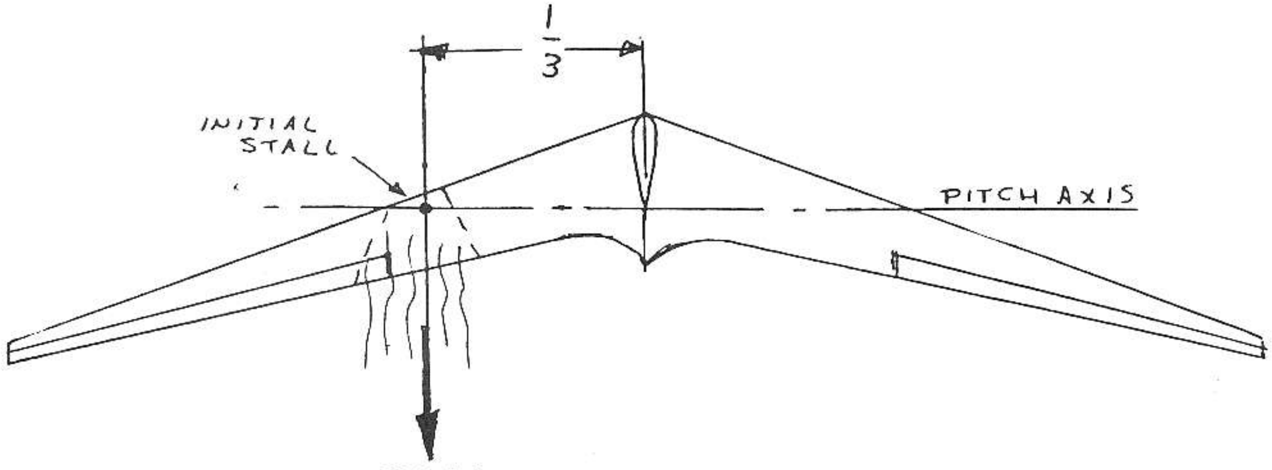

FIGURE A

that the relationship between span and lift was constant.

Today, one rarely sees a true elliptical wing, as other factors dictate its ideal shape. The straight tapered wing, for instance, is lighter and easier to build, and these are factors which usually outweigh the advantages of the elliptical wing.

Since lift and weight are equal in straight and level flight, one needs to find out how the weight of the wing on a cantilevered sailplane changes with its shape and taper when the span is constant.

Let's look at flight characteristics. For good roll control, the airfoil should be thin in the aileron area, while a thick airfoil is needed at the root to obtain an acceptable weight/strength ratio. Since the sailplane will be thermaling near the wing's maximum lift capability, its stall characteristics must be closely studied, both during turns and level flight. If air separation first occurs near one tip—which is likely due to the thin airfoil used there—the roll will quickly stall additional portions of the wing due to its downward movement, and the asymmetric lift can not be overcome by the ailerons.

In a sweptback flying wing, the conditions are somewhat different. Here the flow separation occurs initially at a point about ⅓ of the halfspan, right where the center of pressure and the aircraft's center of gravity are located (see **Figure A**); thus no upsetting moment is created. Asymmetric lift can be controlled by the ailerons, since these still work in undisturbed airflow. If the separation should occur on one side only, a momentum is created around the yaw axis, because a stalled wing has a large increase in parasite drag, which slows the wing despite the disappearance of induced drag. Normally when ailerons are used to control the asymmetry, adverse yaw should not be generated to cancel out the momentum, as directional control should be maintained even with rudders of low efficiency.

Now, let's see how we can satisfy all requirement for a fully-controllable stalled flying wing, and thereby avoid involuntary spins. Most pilots will think of stability as the primary requirement. This is not true! What is needed is the proper distribution of moment around all three axis, and the ability to fly out of any upset.

Correct moment around the pitch axis requires that the center of pressure and center of gravity lie on a line at 25% of the wing chord. The conventional elliptical-shaped wing without wash-out has an ellipticaly-shaped lift distribution curve at all angles of attack, and the center of pressure in Y-direction on a half-wing can be expressed as:

$$\text{Y ell.} = 0.42\ \left(\frac{b}{2}\right).$$

This lift distribution is not desirable, since the point along the wing where the airflow first separates, *can not* be determined.

The desired bell-shaped lift distribution curve can be obtained on any wing by the appropriate amount of twist or wash-out. The center of pressure will then be located near ⅓ of the halfspan, and moves along the wing with changes in angle of attack. On a flying wing sailplane with built in wash-out, one can obtain the desired lift distribution simply by moving the wing tip elevators, thus obtaining a C_L corresponding to the best L/D ratio.