# OPTIMUM SWEEP ANGLE

Nearly all of the best performing tailless aircraft exhibit a leading edge sweep angle of $20^\circ$, and we thought it might be an interesting excercise to attempt to determine why this might be so.

As we've mentioned in a previous column, it is sometimes convenient to think of a tailless aircraft as actually having a tail by assuming the tail is a part of the wing.

The "tail" on a plank design can be considered to be the rear 20 to 25% of its reflexed airfoil.

On a swept wing, the stabilizing "tail" is the outer portion of the wing, near the tips.

A tailless airplane must have some portion of the wing capable of applying the downforce needed to counteract the pitching moment generated by the lift producing section of the wing. Planks thus use reflexed sections, swept 'wings use aerodynamic twist to provide this force.

We've previously published a set of computer routines which assist in picking airfoils for root and tip while assuring stability in pitch. With some experimentation, it's possible to design a stable swept wing with a minimum of physical (geometric) washout. Excessive washout, while providing increased stability, will make a swept 'wing behave much like a plank with excess reflex - the 'wing's speed range and maneuverability will suffer.

Those of you who have experimented with the above mentioned computer routines will have also noticed one way of reducing the amount of washout (twist) needed is to make the sweep angle greater. Unfortunately, this has three negative effects.

(1) The air moving over the wing will tend to move more toward the end of the wing, rather than the trailing edge. This is called cross span flow and is something to be avoided.

Cross span flow means the air is no longer following the airfoil; rather, it is following the spar line. The boundary layer gets very deep very fast in this situation, and laminar separation can occur at odd and unexpected places along the span. This is not only drag producing, it can be downright dangerous. Imagine separated flow over the wing tips ("tail") and the resulting loss of stability!

(2) Large amounts of sweep make steep towline launches very difficult, as any yaw is immediately translated into a large rolling force.

(3) It becomes more difficult to construct a torsionally rigid wing as sweep increases.

While planks do not suffer from any of these three problems, we want better performance than a plank has to offer. What we're looking for is sufficient sweep to improve performance substantially above that of the plank configuration while at the same time avoiding excessive sweep which will lead to further problems.

Assisting us in our search is the necessary vertical fin area. If this fin area is located on the centerline of the aircraft we will most likely need some type of boom (read "fuselage") to get the moment arm long enough. But if winglets are used we can obtain good leverage, the vortex from the wing tips can be controlled, and we can inhibit cross span flow to some extent. By using winglets we can safely get a bit more sweep into the design.

Aspect ratio is a determining factor when computing the sweep angle needed for a given level of stability. A look at the formulae shows sweep is given in terms of a ratio equal to sweep distance divided by average chord. A low aspect ratio dictates a greater angle of sweep, all other things being held constant. While a higher aspect ratio will decrease the sweep angle needed, it can also lead to frail structures, just as with conventional tailed aircraft.

So it turns out the $20^\circ$ angle is a compromise, and an excellent one! Twenty degrees is enough sweep to provide stability for a number of airfoil combinations without resorting to reflexed sections over the majority of the span; it does not promote uncontrollable cross span flow; it allows steep winch launches without the worry of yaw induced roll; it does not hinder the construction of torsionally rigid wings.