A (CRUDE) EXPLANATION OF WING TIP STALL AND THE NEED FOR WASHOUT

By George White

I was recently told by Gene Smith, and I've seen the same information elsewhere, that the concept of adding washout to the wing tips of a model is more important for wing planforms which are elliptical or have a swept back leading edge. Having seen Gene's models fly, I accepted that as the straight word, but my curiosity as to why that's true got the best of me. Having a son who's an aero engineer, I passed the question to him, hoping I could get an answer that a simple-minded guy like me could understand. He allowed as how the answer is really not all that simple, but there are some basic principles which help make sense, considering the low speeds we deal with on rubber models and the glide speeds on all our models.

The term "tip stall" always comes up in the discussion of trimming a model, meaning that airflow separation (stall) occurs at the wing tip, resulting in loss of lift before the wing root reaches a stall. Of course, if both wing tips stall at the exact same airspeed and time, which with a model seldom happens, the model should just mush straight forward with no problem. But, when they don't stall at exactly the same airspeed or time, roll forces are created which will, if not offset by other forces such as dihedral or the vertical area forward of the center of gravity, create a tendency to spiral. (See also Tom Arnold's article entitled "Forward Fins in the Fast Lane," in the Jan/Feb 2005 issue of this exciting rag, and the article entitled "Stability" in the Nov/Dec 2005 issue).

Having said that, the question remains as to why the wing tip might stall before the wing root stalls, assuming that the angle of attack is the same throughout the span. We get into such factors as spanwise airflow, aerodynamic twist (reduced camber from root to tip), induced drag, circulation theory of airflow over the wing, wing tip vortices, etc., the interactions of which are beyond my ability to understand, much less discuss. For those inclined to dig into this subject to the extreme, interesting references can be found on line at:

http://flighttest.navair.navy.mil/unrestricted/FTM108/c3.pdf; and
http://www.flyingmag.com/article.asp?article_id=170&print_page=y,

the latter of which is an article defending the "Hershey Bar" wing on Piper Cherokees. Those are the sources for the extremely simplified discussion which follows.

Cutting to the chase, several statements seem to be relevant to understanding the the big WHY. The ideal characteristics of a wing should result in airflow separation (stall) beginning on the trailing edge of the wing root and progressing gradually forward and outboard, allowing the aircraft to "mush" forward without rolling. Lift is a function of cord, among a great many other things, but for our purposes, that's the critical factor. For an equivalent airfoil shape, the shorter the cord the less lifting ability it has. Thus for a given angle of attack a shorter cord at the tip means a greater lift loading per square inch compared to the greater cord at the root on an elliptical or swept back leading edge wing. The greater that lift loading, the greater the stall tendency at a given angle of attack. Wing stall starts at that point along the span which first reaches its maximum lift coefficient, and the shorter cord at the tip will reach that maximum lift coefficient first due to the higher lift loading. In other words, the shorter cord at the tip of a tapered or elliptical wing is always closer to the stall limit for a give angle of attack, and the airflow will separate there before it does at the larger cord at the root.

Interestingly, the rectangular wing will normally stall first at the root due to spanwise airflow reducing the lift coefficient at the tip, thus leaving the tip further below he lift coefficient limit (i.e. stall point) than the root as the wing approaches the critical angle of attack. How that spanwise airflow unloads the wing tip, thus raising its stall speed on a rectangular wing is beyond the scope of this discussion, but if you have great curiosity, check out the references above.

All this offers the explanation as to why, in the absence of other considerations such as needing to counter thrust vectors, torque, etc., we might need to reduce the wing tip angle of attack relative to that at the root on a tapered or elliptical wing by adding a bit of washout to “unload” the wing tips and the tendency to stall before the root. It is also apparent that there is less need to concern ourselves with tip stall on rectangular wings and adding washout there, other factors being equal, may be accomplishing little if anything other than loss of lift.