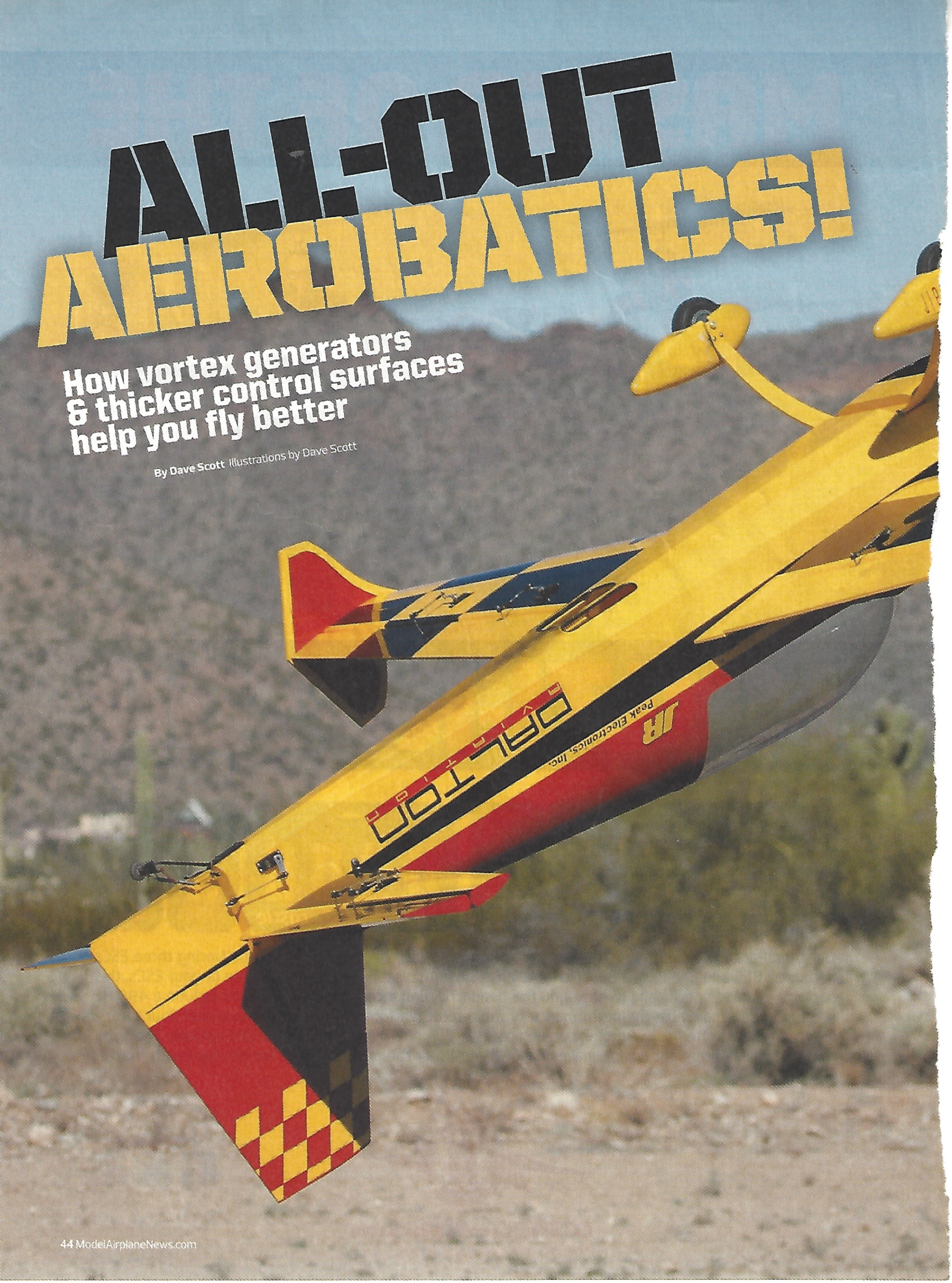
ALL-OUT AEROBATICS!

How vortex generators & thicker control surfaces help you fly better

By Dave Scott Illustrations by Dave Scott



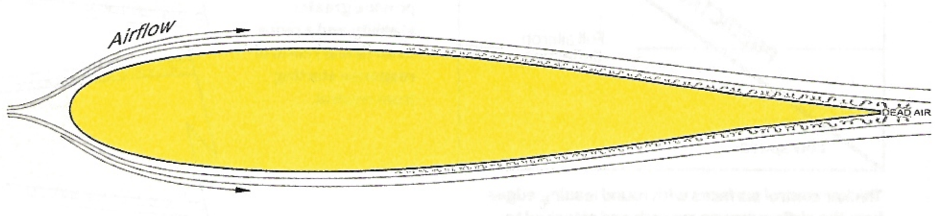
What effect does surface friction have on airflow over the wing, tail, and control surfaces? In this article, we'll investigate the answer and then offer some common solutions to overcome this phenomenon and significantly improve handling and control. Although you may not realize it, you encounter the effects of the control surfaces being surrounded by disturbed/turbulent air every time you fly in the form of erratic, uneven control responses — especially at slower airspeeds. This is especially troublesome during novice flight training because so much of the flying is done at slower speeds. This phenomenon is also highly undesirable when performing aerobatics due to the fact that the severity of the disrupted airflow varies with airspeed and angle of attack. Since the airspeed and angle of attack are constantly changing during aerobatics, the ensuing uneven control responses interfere with your ability to predict and positively control your maneuvers. This becomes an even greater issue when flying in windy conditions, as you often need immediate and positive corrections.

BOUNDARY LAYER BASICS

Surface friction causes the air in contact with the wing, tail, etc. to slow and become turbulent. Away from the surface, the air molecules are less and less turbulent until a point is reached where the airflow is smooth. The layer of air from the surface to the point where there is no measurable slowing is known as the "boundary layer." As the airflow progresses aft, the turbulent boundary layer becomes progressively thicker and more unstable. You can see this phenomenon when wind contacts the surface of a lake and creates ripples that then grow into larger waves.

The turbulent boundary layer produces more drag, but more important, it is prone to causing airflow separation, which leads to an earlier and more severe stall, and degrades the effectiveness of control surfaces, especially the ailerons. Small control surface deflections within the turbulent boundary layer tend to produce sluggish and/or erratic responses, particularly at slower airspeeds. To begin to achieve positive control, pilots must apply larger inputs to deflect the surface into smoother air, at which time there is an exponential increase in the rate of response.

Traditional beveled leading-edge control surfaces



Surface friction causes the air in contact with the wing's surface to become stagnant and/or turbulent. As the airflow progresses aft, the turbulent boundary layer then becomes progressively thicker and more unstable.

further disrupt the already turbulent airflow as a result of the air tripping over the bevel's sharp corners, and therefore compound the uneven control response. The most noticeable aspects of flying with conventional beveled control surfaces are difficulties keeping the wings level, making fine adjustments, and having response rates that exponentially speed up and slow down with airspeed changes. These all interfere with the pilot's ability to precisely predict the effects that his control inputs will have on the airplane. Tradition, ease of manufacture, and the dominance of 3D designs that require huge control surface movements are why this primitive design continues to be used. Because of this same design, many manufacturers have to resort to sealing the gaps to try to limit some of the inherent airflow disruption and potential for flutter.

THICKER CONTROL SURFACES & POSITIVE CONTROL

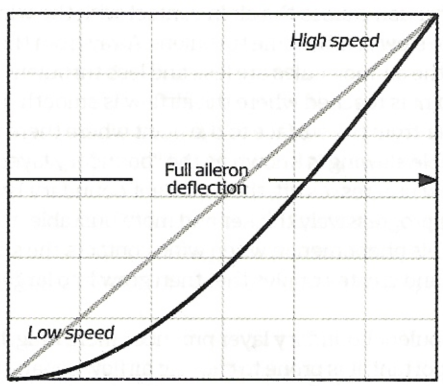
The airflow is smoother slightly away from the surface of the wing or tail, so incorporating control surfaces that are a little thicker will place the physical surface of the ailerons, elevator, and rudder flush with the smoother airflow to improve stability and control by as much as 50%! A round leading edge applied to a control surface further improves control by providing a smoother contour for the airflow to pass over the surface without becoming turbulent.

Thicker control surfaces with round leading edges are used on nearly every full-scale aerobatic aircraft designed since the 1980s, including every full-scale Extra, Edge, MX, Cap, modern Pitts, etc. The improved control they provide has not only helped these aircraft dominate World Aerobatic Championships and individual competitions ever since, but raised leading-edge surfaces are largely responsible for the greatly expanded control envelopes demonstrated by modern aerobatic aircraft today!

Here are some specific benefits of thicker control surfaces with round leading edges:

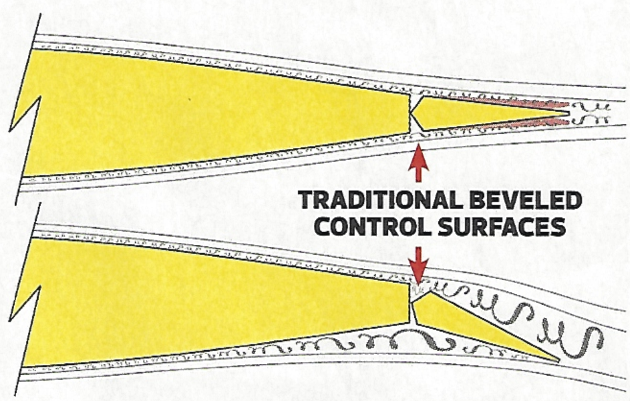
- Pilots experience a more predictable linear one-to-one correlation between their control inputs/intentions and the response of the plane, especially when making smaller inputs.
- The minimum controllable airspeed is lowered on all aircraft, thus expanding their flight envelopes.
- There is greater stability in turbulent air and smoother, more positive control responses during both aerobatics and low-and-slow flight during landing.
- The potential for flutter is significantly

CONVENTIONAL NON-LINEAR CONTROL RATE RESPONSE

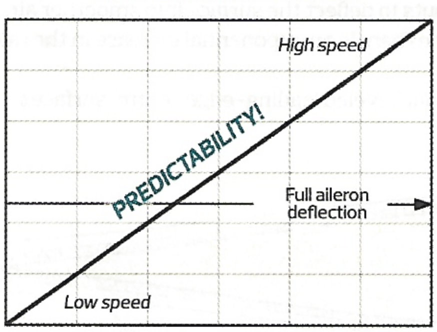


Traditional beveled surfaces produce an initial sluggish response and an irregular response rate that impairs a pilot's ability to predict how the plane will respond to commands, especially at lower airspeeds.

Surface (skin) friction causes a turbulent boundary layer to develop and surround all the control surfaces Traditional beveled control surfaces with sharp corners further aggravate the already disturbed air. The result is uneven control responses and an increased potential for control surface flutter!

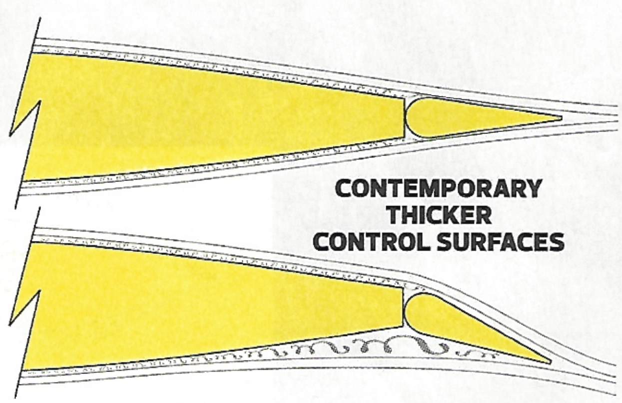


OPTIMUM LINEAR CONTROL RATE RESPONSE



Thicker control surfaces with round leading edges help the airflow remain smooth and attached to the control surfaces when deflected for maximum control authority at all airspeeds.

Thicker control surfaces with round leading edges achieve a smoother airflow over them and therefore provide greater stability and a more even (linear) control response starting from neutral.

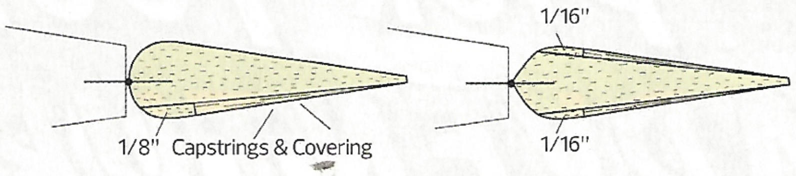


reduced (making sealing the gaps unnecessary).

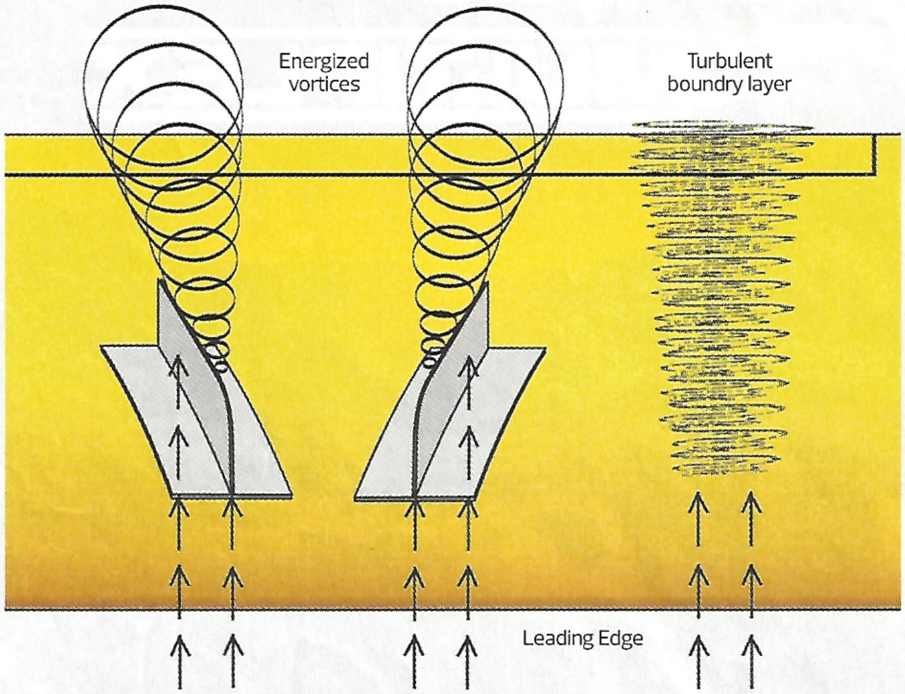
The drawbacks of thicker control surfaces are the hassle of having to build them yourself and, unless the hinge axis points are recessed into the control surface, the round leading edge can limit surface travel. Therefore, while 3D flight would also greatly benefit from thicker surfaces, this design is primarily applicable to precision aerobatics and scale flying, where the surface deflections are not so extreme. Thicker control surfaces all around would be optimum, but the ailerons, i.e., control of the wing, are most important. To achieve the increased thickness, you can either purchase thicker stock balsa or build up the leading edge of the provided ailerons with lightweight strips of balsa on one side and re-center the hinges or add strips of balsa to both sides.

VORTEX GENERATORS

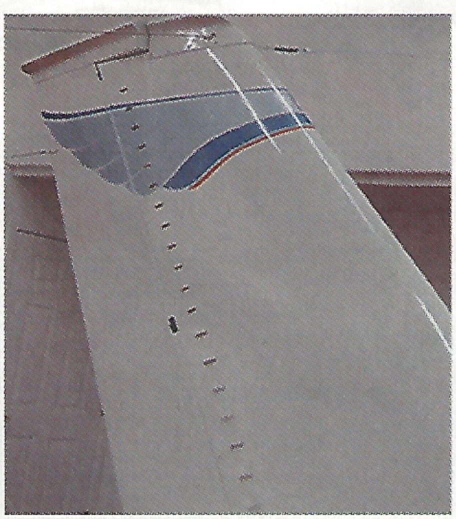
When it's not practical to install thicker control surfaces on an existing model, vortex generators can be used to accomplish the same effect, if not more. Vortex generators typically consist of small vanes or fins positioned near the wing leading edge. These energize the boundary layer by creating vortices (tiny tornados) that pull fast-moving air down through the previously stagnant or turbulent boundary layer near the surface. By energizing the airflow, vortex generators enable the wing to operate at higher angles of attack before stalling,

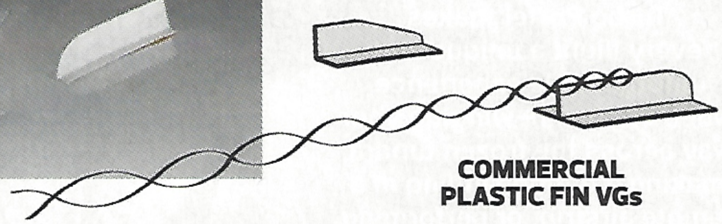


Rule-of-thumb: Raise the aileron, elevator, and rudder approx 1/16" each side – 3/32" to 1/8" thicker overall.

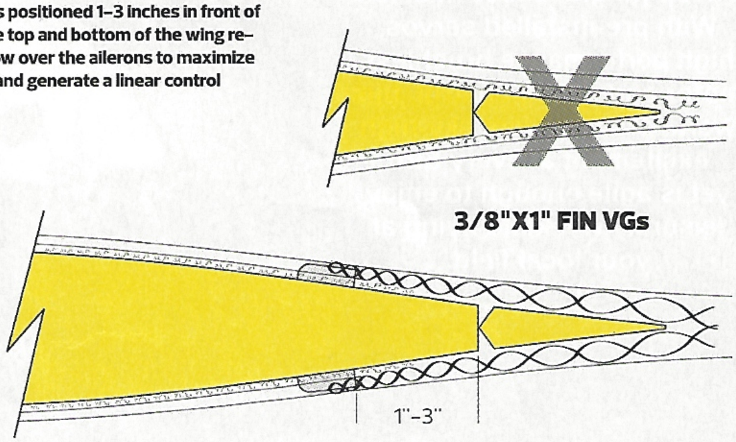


Vortex generators are positioned obliquely (e.g., 10–20 degrees) so that they have an angle of attack with respect to the oncoming airflow (thus causing the airflow to spill over eachVGand form the highly energized vortex).





Vortex generators positioned 1–3 inches in front of the ailerons on the top and bottom of the wing re-energize the airflow over the ailerons to maximize control authority and generate a linear control response.



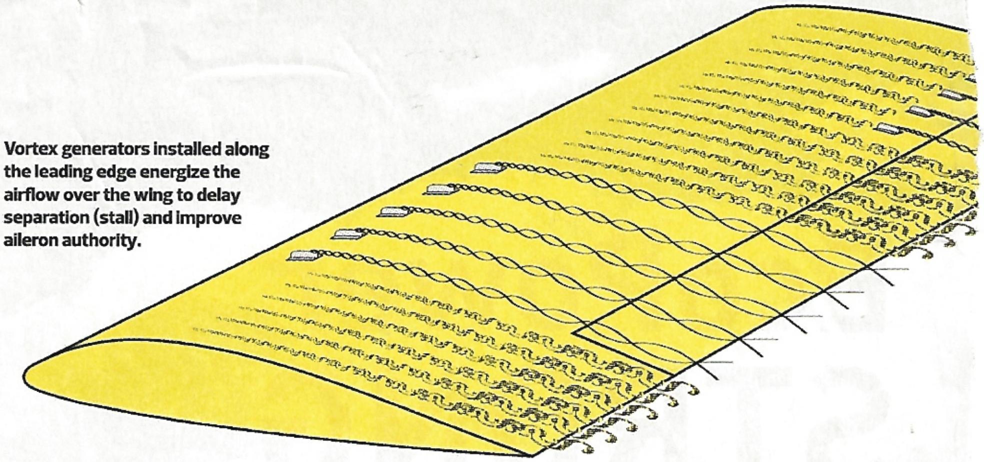
provide gentler stall characteristics, and increase control and stability, especially at lower airspeeds.

Vortex generators are revolutionizing aircraft performance, and thousands of full-scale aircraft have been fitted with them over the last couple of decades to improve short-field performance and low-speed handling to a degree that is hard to believe until you experience it. When lowering the stall speed is not important due to the model's already mild stall characteristics, vortex generators can be placed directly in front of the ailerons and/or rudder and elevator strictly to enhance control authority by reattaching and energizing the airflow over surfaces.

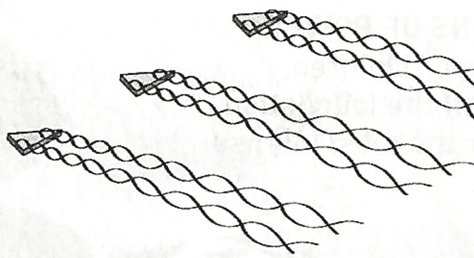
While the size, shape, and spacing of vortex generators vary, they are typically rectangular (e.g., 3/8 x 1 inch) and are attached with epoxy or clear silicone contact adhesive. When the goal is to both lower the stall speed and improve aileron authority, they are positioned in a spanwise line (roughly 2 to 3 inches apart) on the front third of the wing. When the goal is strictly to improve aileron authority, the vortex generators are installed roughly 1 to 3 inches in front of the hinge line on the top and bottom of the wing in front of the ailerons.

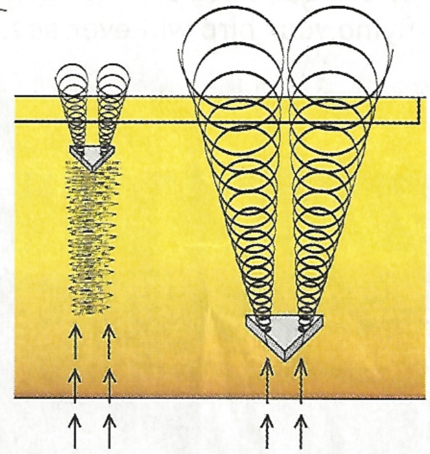
The tradeoffs for using traditional fin vortex generators are an approximate 1% reduction in top speed, but more practically, they make the wing harder to clean and are prone to getting knocked off. The contemporary solution seen on more and more modern aircraft is to use flat triangle vortex generators instead. 1st U.S. R/C Flight School bends its fin VGs out of clear plastic windshield material and cuts its flat triangle vortex generators out of 3/32-inch-thick balsa, then secures them with clear adhesive.

While optimizing control of the wing is most important, vortex generators are sometimes installed on the horizontal and vertical tails to improve elevator and rudder effectiveness and achieve a more linear response. They are also quite effective on the turtle deck in front of the vertical stabilizer to help reduce the annoying tail waggle resulting from the turbulent boundary layer as well as hinge slop and slop in the rudder servo.



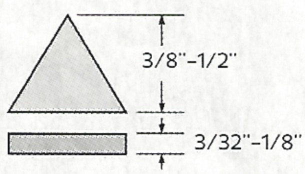
Vortex generators installed along the leading edge energize the airflow over the wing to delay separation (stall) and improve aileron authority.

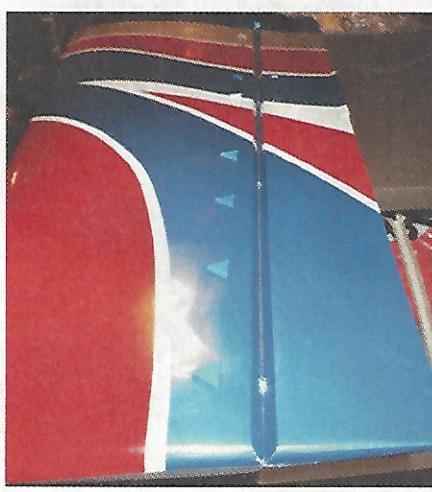


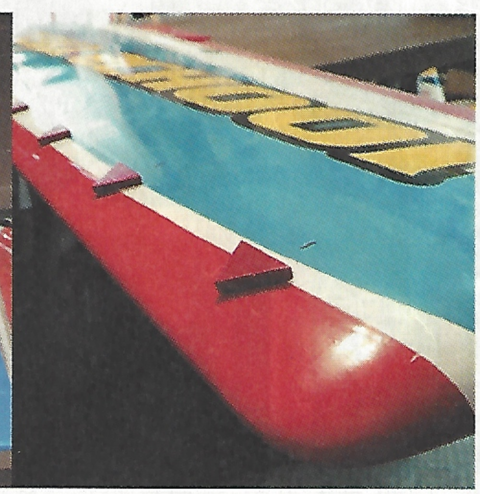


Vortex generators positioned in front of the ailerons, on the top and bottom of the wing, re-energize the airflow over the ailerons to maximize control authority and generate a linear control response.

CONTEMPORARY FLAT BALSA TRIANGLE VGs







CONCLUSION

1st U.S. R/C Flight School programs are predicated on a belief that one improvement is only that, yet several improvements can add up to have a significant impact! Because of this, we use thicker control surfaces and/or vortex generators on every airplane in the flight school training fleet. They improve each pilot's ability to maintain positive control at slow speeds and in wind, as well as tame the tip-stall tendencies of certain models. Most important, thicker control surfaces and vortex generators make training more consistent and therefore more enjoyable for both student and teacher by ensuring the in-flight results more closely follow the intentions of the pilot. The major drawback is that once you've experienced the solid control feel they provide, you'll never again be satisfied with conventional handling!