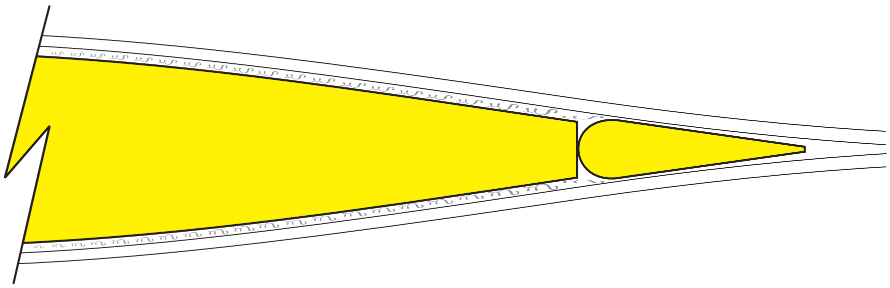
Thicker Control Surfaces & Vortex Generators Explained

Modern mods that significantly improve any plane's handling

By Dave Scott. Instructor, 1st U.S. R/C Flight School
Illustrations by Dave Scott



Dave Scott is a champion full-scale aerobatic competitor and airshow pilot. He founded 1st RC Flight School and has professionally trained more than 2000 RC pilots of all skill levels. His groundbreaking manuals and articles feature the accelerated training techniques developed during his 14,000 hours of instruction and experience setting up and test flying over 1000 airplanes at his school. More information about his books and school can be found at www.rcflightschool.com

Introduction

The following article describes the effect that surface friction has upon disrupting the airflow over the surface of the wing, tail, and control surfaces, and then offers up some modern solutions to overcome this phenomenon in order to significantly improve handling and control.

Although most pilots are unaware of this phenomenon, they encounter the inherent effects of the control surfaces being surrounded by disturbed/turbulent air every time they fly in the form of erratic uneven control responses, especially at slower airspeeds. This phenomenon can therefore be particularly troublesome during novice flight training since 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 changes in airspeed and angle-of-attack. I.e., Since airspeed and angle-of-attack are constantly changing during aerobatics, the ensuing uneven control responses end up interfering with a pilot's ability to predict and positively control his maneuvers. This becomes an even greater issue when flying in windy conditions due to the importance of often needing 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 will be 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 severe (figure 1). You can see this same 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 importantly, it is prone to causing airflow separation leading to an earlier and more severe stall, along with degrading the effectiveness of the control surfaces, especially the ailerons.

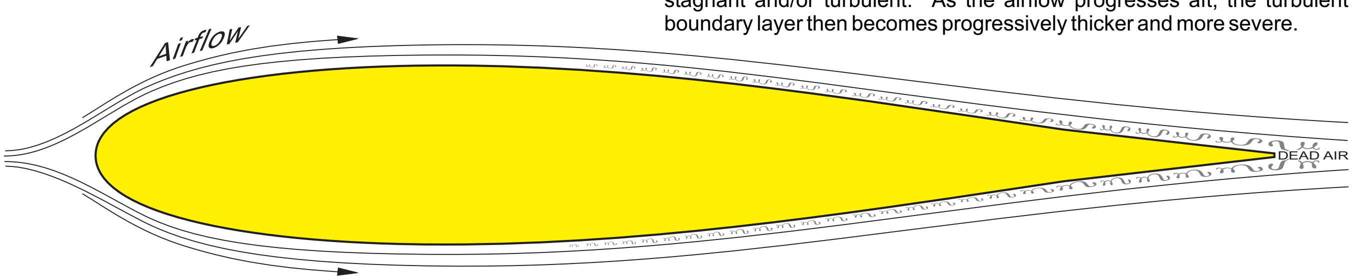
For example, small control surface deflections within the turbulent boundary layer tend to produce sluggish and/or erratic responses, particularly at slower airspeeds. In order to begin achieving positive control, pilots must apply larger inputs to deflect the surface into smoother air, at which time there is an exponential increase in the rate of response.

Traditional beveled leading-edge control surfaces further disrupt the already turbulent airflow as a result of the air tripping over the bevel's sharp corners, and thus further compound the uneven control response (figure 2).

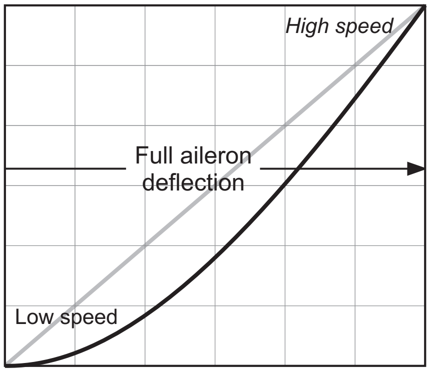
The most noticeable aspects of flying with conventional beveled control surfaces are difficulties keeping the wings level, i.e., making fine adjustments, and response rates that exponentially speed up and slow down with airspeed changes -- thereby interfering with the pilot's ability to precisely predict the effects that his control inputs will have on the airplane.

Tradition, ease of manufacture, and the dominance of 3D designs requiring huge control surface movements are the reasons that this primitive design continues to be used. It is also because of this design that many manufacturers have to resort to sealing the gaps to try to limit some of the inherent airflow disruption and potential for flutter.

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 severe.

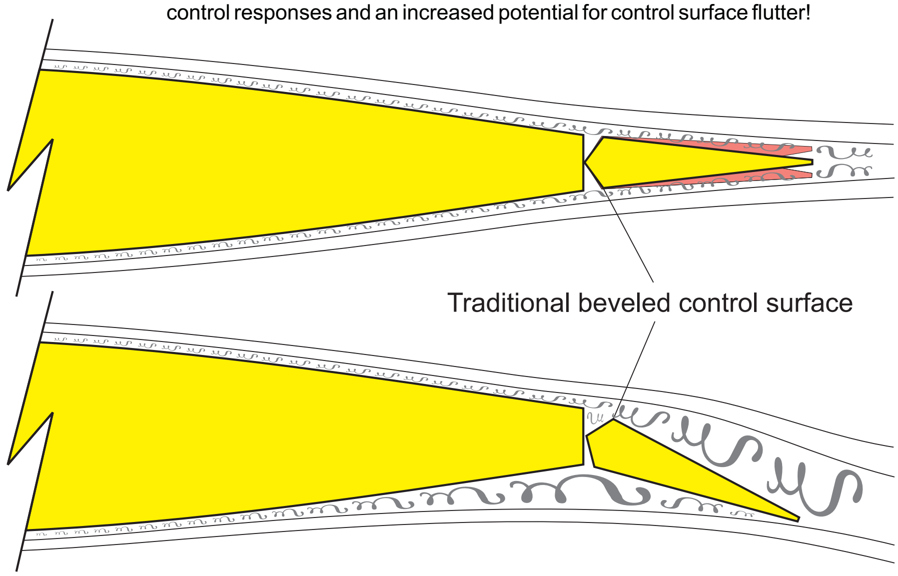


Conventional non-linear control rate response



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 that surrounds all the control surfaces. Traditional beveled control surfaces with sharp corners further aggravate the already turbulent air. The result is uneven control responses and an increased potential for control surface flutter!



Thicker Control Surfaces and Positive (Linear) Control

The airflow is smoother slightly away from the surface of the wing or tail. Thus, incorporating slightly thicker control surfaces places the physical surface of the ailerons, elevator, and rudder flush with the smoother airflow, thereby improving stability and control 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 (figure 3).

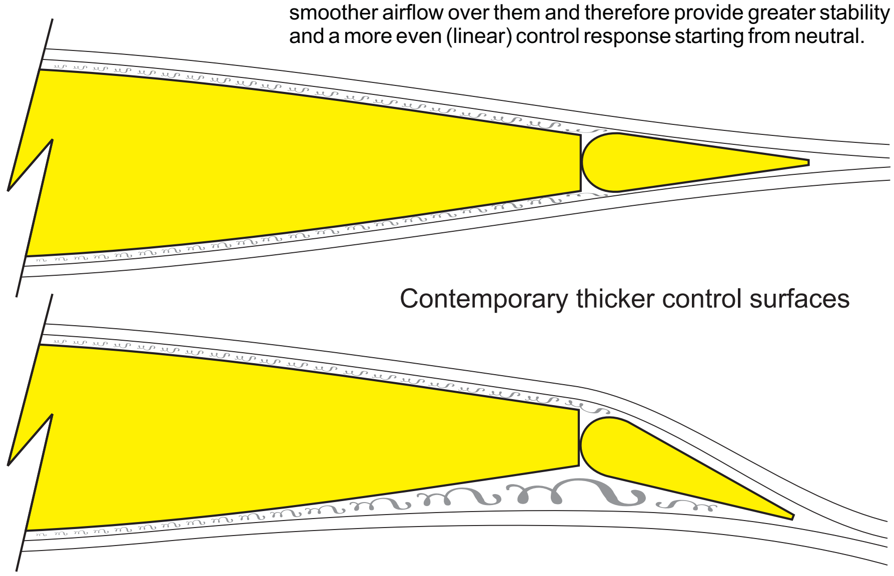
Thicker control surfaces with round leading edges are utilized on nearly every full-scale aerobatic aircraft designed since the 1980's, including every full-scale Extra, Edge, MX, Cap, modern Pitts, etc.. The improved control they provide has not only helped these aircraft dominate World Aerobatic Championships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

Specific benefits of thicker control surfaces with round leading edges are:

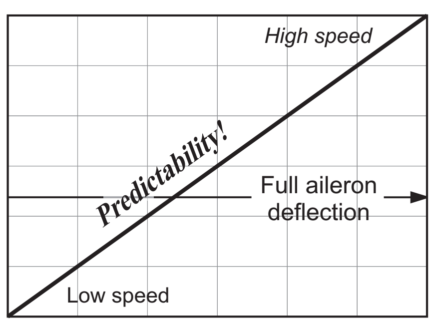
• Pilots experience a more predictable linear 1-to-1 correlation between their control inputs/intentions and the response of the plane, especially when making smaller inputs.

• The minimum controllable airspeed (MCA) is lowered on all aircraft, thus expanding their flight envelopes.

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.



Optimum linear control rate response



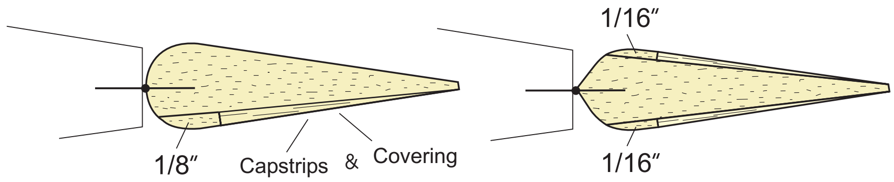
Thicker control surfaces with round leading edges help the airflow remain smooth and attached to the control surfaces when deflected for maximum control authority at all airspeeds.

• Greater stability in turbulent air and smoother more positive control responses both during aerobatics or when low and slow during landing.

• The potential for flutter is significantly 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 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.

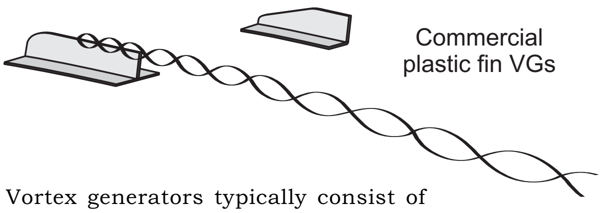
Thicker control surfaces all around would be optimum, but it is the ailerons, i.e., control of the wing, that is most important. To achieve the increased thickness, you can either purchase thicker balsa stock, or, build up the leading edge of the provided ailerons with lightweight strips of balsa on one side and re-center the hinges, or, add balsa strips to both sides.

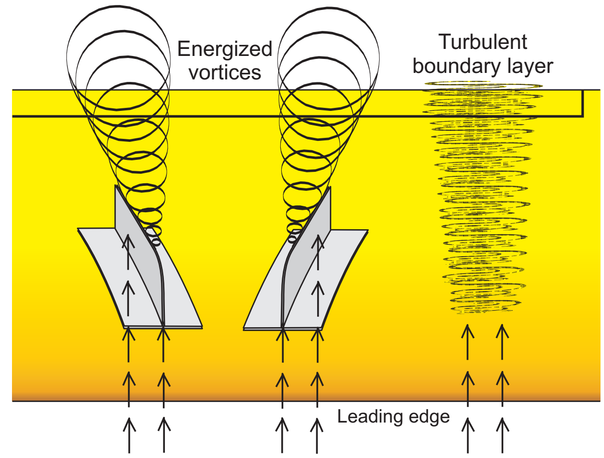


Rule-of-thumb: Raise the aileron, elevator, and rudder approx. 1/16" each side - 3/32" to 1/8" thicker overall.

Vortex Generators (Vgs)

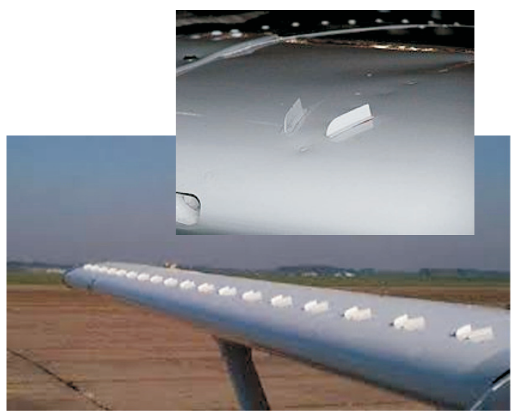
When it is not practical to install thicker control surfaces on an existing model, vortex generators (VGs) can be used to accomplish the same effect, if not more (figure 4).





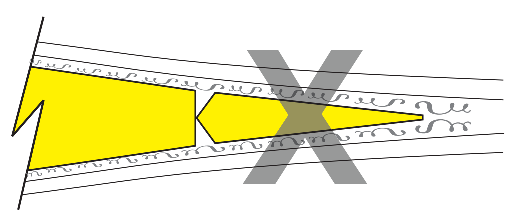
Vortex generators are positioned obliquely (e.g., 10-20 degrees) so that they have an angle of attack with respect to the oncoming airflow (thus causing the airflow to spill over each VG and form the highly energized vortex).

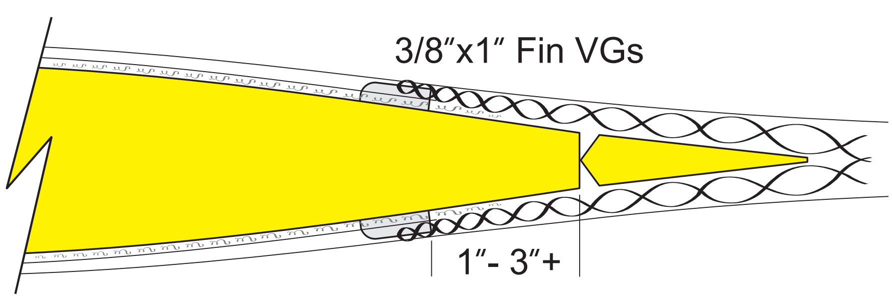
Vortex generators typically consist of small vanes or fins positioned near the wing leading edge that energize the boundary layer by creating vortices (tiny tornados) that pull fast-moving air down through the previously discussed stagnant or turbulent boundary layer near the surface. By energizing the airflow, VGs enable the wing to operate at higher angles-of-attack before stalling, provide gentler stall characteristics, and increase control and stability, especially at lower airspeeds.



Vortex generators are indeed 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.

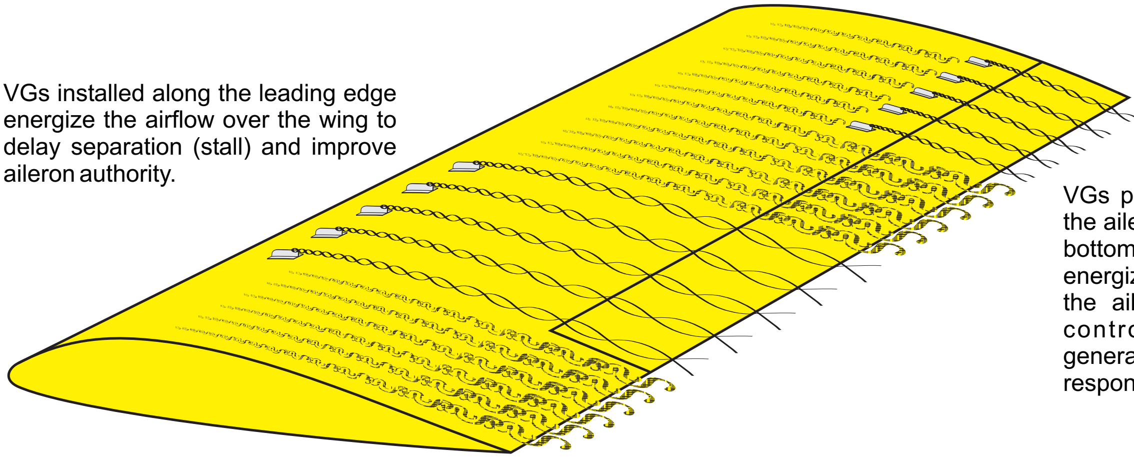
VGs positioned 1”-3” in front of the ailerons on the top and bottom of the wing re-energize the airflow over the ailerons to maximize control authority and generate a linear control response.





When lowering the stall speed is not important due to the model's already mild stall characteristics, VGs can be placed directly in front of the ailerons, and/or ahead of the rudder and elevator, to enhance control authority by reattaching and energizing the airflow over those surfaces (figure 5).

1st U.S. R/C Flight School bends its fin VGs out of clear plastic windshield material. While the size, shape, and spacing of VGs vary, they are typically rectangular (e.g., 3/8”x1”) and are attached with epoxy or clear silicone contact adhesive. When the goal is to

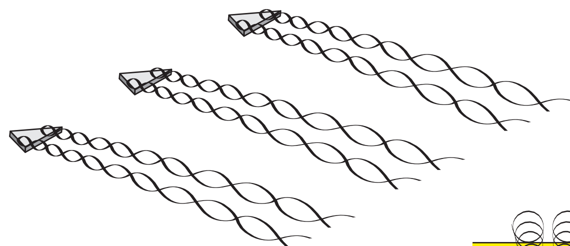


both lower the stall speed and improve aileron authority, they are usually positioned in a spanwise line (roughly 2”-3” apart) on the front third of the wing (figure 6).

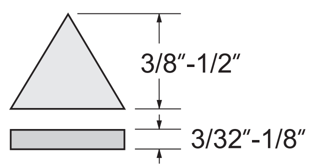
When the goal is strictly to improve aileron authority, the VGs are installed roughly 1”-3” in front of the hinge line on the top and bottom of the wing in front of the ailerons.

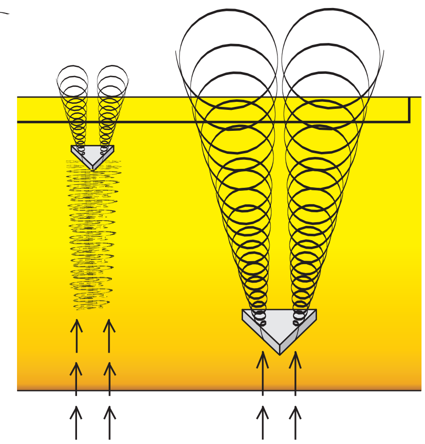
The tradeoffs for utilizing traditional fin VGs are an approx. 1% reduction in top speed, but more practically, they make the wing harder to clean and are prone to getting knocked off. The contemporary solution seen on more and more modern aircraft is to use flat triangle VGs instead (figure 7). While this style of VG is typically made out of thin clear plastic on full-scale aircraft, the author cuts his flat triangle VGs out of thicker 3/32” thick balsa and secures them with clear GOOP™ contact adhesive for best results.

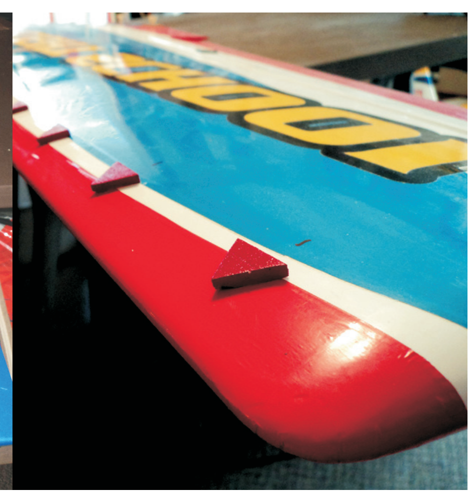
While optimizing control of the wing is most important, VGs are also sometimes installed on the horizontal and vertical tails to improve elevator and rudder effectiveness and achieve a more linear response. VGs are also quite effective on the turtle deck in front of the vertical stabilizer to help reduce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



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! Hence, thicker control surfaces and/or VGs are utilized on every airplane in the flight school training fleet to improve each pilot's ability to maintain positive control at slow speeds, in wind, as well as to tame the tip stall tendencies of certain models. Most importantly, thicker control surfaces and VGs 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! Happy flying!