Basic sizing checks for homebrew RC thermal gliders

by Mark Drela

If you do a lot of homebrews, it really pays to do some simple sizing checks for vertical tail, horizontal tail, and Equivalent Dihedral Angle (EDA). It can save a huge amount of aggravation and possibly unwarranted disappointment with a new design.

Specifically, you should always calculate the following three quantities:

Vh = (hor_tail_area/wing_area) x (hor_tail_arm/mean_wing_chord)
Vv = (ver_tail_area/wing_area) x (ver_tail_arm/span)
B = EDA x (ver_tail_arm/span) / CL_therm

where EDA is in degrees, and CLtherm is the typical CL during slow thermalling.

It's OK to just assume CLtherm=0.7 for big gliders and CLtherm=0.6 for HLGs. For a V-tail, first compute the equivalent hor_tail_area and ver_tail_area, as described in <http://www.charlesriverrc.org/articles/design/markdrela_vtailsizing.htm>

Vh = horizontal tail volume, indicates mainly pitch stability.
Vv = vertical tail volume, indicates mainly yaw damping and rudder power.
B = Blaine Rawdon's parameter, indicates spiral stability...

B > 5 spirally stable
B = 5 spirally neutral
B < 5 spirally unstable

B also approximately indicates the degree of roll power available to a poly glider, provided Vv is reasonable.

For a good-handling poly glider you want to be in these ranges:

Vh = 0.3 - 0.6 (I like 0.4 - 0.45)
Vv = 0.02 - 0.04 (I like at least 0.03)
B = 4.0 - 6.0 (I like 5.0 - 5.5)

For an aileron TD glider you want to have:

Vh = 0.3 - 0.6
Vv = 0.015 - 0.025 (I like at least 0.025)
B = 2.0 - 5.0 (I like at least 3.0)

A DLG wants a huge amount of yaw damping:

Vv = 0.05 - 0.06 is not out of line.

Having said all that, it should be mentioned that moments of inertia influence the choices for the Vh and Vv values. A glider with an unusually small pitch inertia because of a very light tail unit can get away with using a smaller stab (smaller Vh to be more precise). Similarly, a glider with exceptionally light wing tips will have small yaw inertia and can get away with a smaller than usual. And of course gliders with larger than normal inertias will require larger than normal Vj and Vv values.

Comment: The Allegro-Lite seems to have a fairly modest tail sizes.

There are no universal values for Vh and Vv which will work well for all aircraft configurations. This is because the Vh and Vv definitions do not account for all factors which influence tail sizing.

First of all, we should state the standard Vh and Vv definitions:

Vh = (hori_tail_area/wing_area) * (tail_length/wing_chord)
Vv = (vert_tail_area/wing_area) * (tail_length/wing_span)

What do these definitions ignore? First let's look at Vh...

Vh ignores the destabilizing influence of the wing's flowfield on the effective angle seen by the stab. This influence is a complicated function of the tail length, since there's a tip-vortex downwash part which increases slowly with distance, and a bound-vortex part which decreases rapidly with distance. The net effect usually decreases with downstream distance. So longer tails require smaller Vh values for the same stabilizing effect.

Vh also ignores the issue of tail aspect ratio and tail airfoil quality, both of which affect the dCL/da lift curve slope of the tail. Increasing the tail's aspect ratio and switching from a slab airfoil to a good (non-deadband!) airfoil will allow a slightly smaller Vh for the same real stabilizing power. The Allegro-Lite has a high aspect ratio stab with a good airfoil immune to low-Re effects. So it can get by with a smaller than usual Vh.

Finally, Vh also ignores the effect on pitch damping, which depends on tail_length2. But pitch damping is usually adequate for any reasonable tail size, so this is a minor consideration in horizontal tail sizing.

Now let's look at Vv...

Yaw damping is the main issue in vertical tail sizing, especially on a rudder/elevator glider. Since Vv is not a measure of damping power, it is simply not a good indicator of vertical tail size. A much better definition which quantifies yaw damping would be

Vv' = (vert_tail_area/wing_area)*(tail_length2*mass/yaw_inertia)

It's less convenient to use since yaw inertia is not easily computed. But Vv' can be estimated in terms of the “radius of gyration”

rg = √(yaw_inertia/mass)

which has the units of length and is typically some fraction of the wing span. A uniform plank flying wing has

rg = √(1/12)*wing_span = 0.289*wing_span (flying plank)

For normal gliders the rg is somewhat less than this formula indicates since they have more stuff concentrated near the center of mass. For the unballasted Allegro-Lite it is

rg = 0.2*wing_span (Allegro-Lite)

and for a highly-ballasted AL it can be as small as 0.1*wing_span.

Equivalent expressions for the yaw damping parameter Vv' are then

Vv' = (vert_tail_area/wing_area)*(tail_length/rg)2

Vv' = Vv * tail_length * wing_span / rg2

In any case, increasing the tail length clearly allows smaller Vv for the same Vv' (which is what really matters). Reducing yaw inertia or adding central ballast, both of which reduce rg, also allows smaller Vv for the same Vv'.

So to get to the original question, the AL with its long tail and very light tips and tail (low yaw inertia) has in fact a quite large Vv' compared to other gliders. This is apparent in its rather nice yaw damping characteristics, especially when ballasted. The Spirit 2m which was mentioned, has a short tail and broad (heavy) tips, and is very wobbly by comparison.

One other issue which often arises in vertical tail sizing is spiral stability. Increasing the tail size tends to worsen spiral instability on most aircraft.

But on r/c gliders with generous dihedral it has a much lesser effect.

For large EDA values it has in fact little or no effect on spiral stability. According to Blaine Rawdon's approximate criterion, we get spiral stability if

$$EDA * (tail\_length/wing\_span) / CL > 5.0$$

This favors a longer tail length, but vertical tail area doesn't enter in.

Another obscure fact is that a spirally-stable glider can become spirally unstable above a certain bank angle in a steady turn. It will hold trim in a shallow banked turn, but will become unstable and try to spiral in above a critical bank angle. The larger vertical tail the larger this critical angle is. The AL has a critical bank angle of about 50 degrees.

Randy Martin's 1/3.5 scale DG-1000 with its canopy ajar on final.
From the EMS kit, this model spans 5.3 meters and weighs approximately 22 lbs.

For more pictures from the JR Aerotow 2004,
see Mark Nankivil's photo essay starting on page 20.