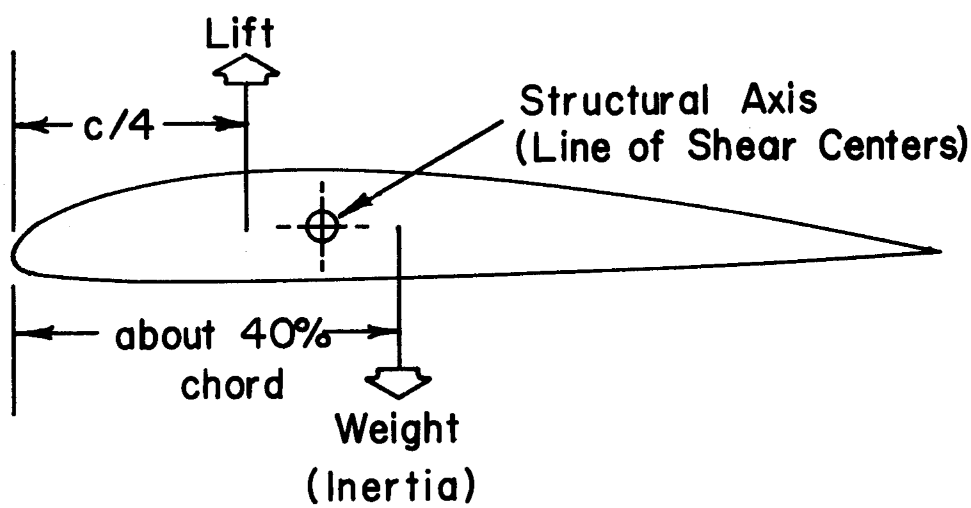
INHIBITING FLUTTER

The description of Project Penumbra which appeared in the October 1990 issue of RCSD elicited several requests for the Penumbra.1 and Penumbra.2 sketches. Additionally, we've received a couple of pieces of correspondence from Bill Kubiak outlining the causes of flutter and offering some possible solutions. (If you'll remember, Penumbra.2 seemed to be very prone to flutter during launch. So severe was the flutter that one launch saw the right winglet shake off!) Bill's explanation is very clear and is applicable to conventional aircraft as well as our tailless creations, so we decided to reprint it here in our column.

"I also am interested in 'wings, dating back to '49 when I was at Northrop and did a small job on the YB-49 and the Snark. My modeling of 'wings, however, is limited to hand launch gliders of various configurations.

"You seem to be concerned with the higher speed of the 'wings and with flutter and other structural considerations. Well, let me throw out a few remarks to see if I can help you a little.

"Consider:



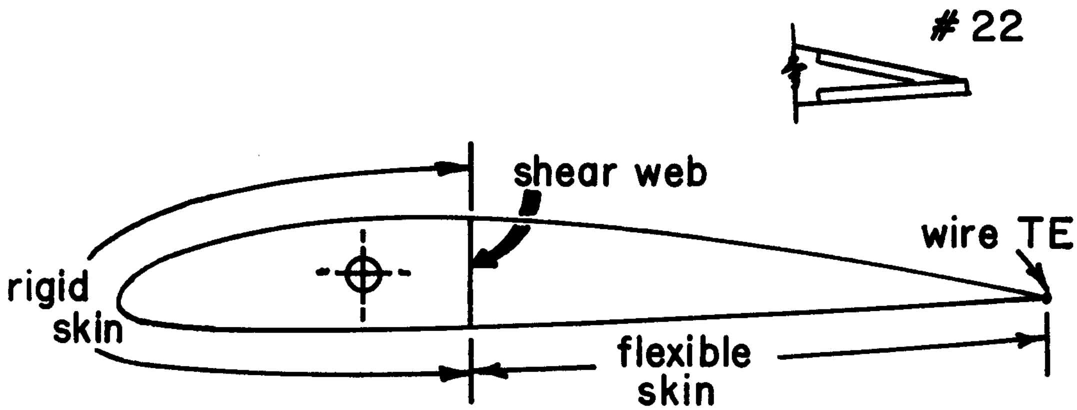
"The structural axis is a point through which you can apply a load without twisting the wing. Up loads ahead of the structural axis cause the wing to twist leading edge up; up loads aft of the structural axis cause the wing to twist leading edge down. The location of the structural axis varies with the design but generally, for enclosed sections, is at or near the centroid of the enclosed area. (The centroid is the center of mass of an object having a constant density. If a wing were composed of foam only, for example, the centroid would be at the CG of the wing.) So it usually happens that the centroid is located as shown above. Since inertia is always opposite to the lift we always have a couple tending to twist the wing about the structural axis.

"The location of the lift vector is pretty well fixed, so the thing to do is move the structural axis forward toward the lift and to move the inertia forward. This would reduce the destabilizing couple. If you went to extremes you might even get the centroid and structural axis ahead of the lift.

"I'm sure you are familiar with balancing an aileron or elevator at its hingeline (or maybe a little ahead) to prevent flutter. The same thing applies to a wing. The structural axis is the hinge line that the wing twists about. If you can get the inertia ahead of the structural axis then an up gust will give a leading edge down twist to the wing, relieving the gust twist.

"As an aside: In the '50's I was at McDonnell Aircraft in the structures department. John Meyer, Chief of Structures, wrote a memo about wing design and flutter. He said that the F3H Demon wing had about 1500 lbs. of structure beyond what was required to take shear and bending loads, just to make that thin sweptback wing flutter resistant. In comparison, an examination of a captured MiG-15 showed that Mikoyan and Gurevich had accomplished the same thing by installing A 60 Lbs. weight in the leading edge of each wing tip. The weight moved the wing CG ahead of the structural axis to reduce or prevent flutter. While it is deliberate heresy to consider ballast weight in an airplane, this is one case of one pound of ballast replacing over 12 lbs. of structure.

"I know that D-tube leading edges are in disrepute because of aerodynamic reasons concerning the discontinuity of curvature at the rear edge of the "D." But, a D-tube leading edge really makes sense from a structural point of view.



"If a wing were to be constructed as shown above, with a D-tube leading edge having a skin rigid enough to carry the shear load and a rear portion consisting of a flexible (Monokote) skin and a wire trailing edge (ala WWI airplanes) the structural axis could be at the C/4. The weight also could be forward so that we could have a very flutter resistant design.

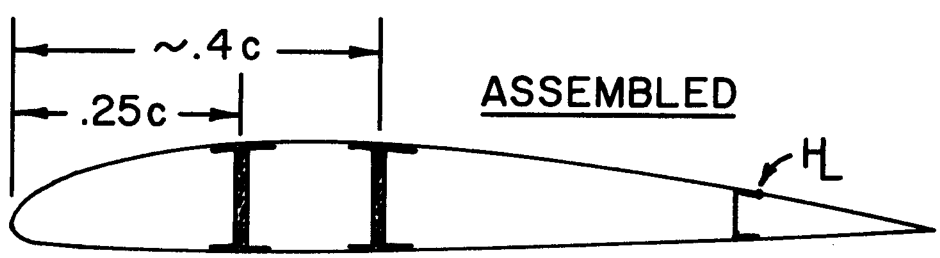
"My canard design #22 for John Borlaug was along these lines except that I didn't use a wire trailing edge. I used two 1/16" thick strips along the trailing edge. These strips are flexible in the vertical direction but are stiff horizontally to carry the Monokote loads. I can attest to the wing being flutter proof. I saw John perform a few horrendous dives without any sign of flutter. #22 met its demise while John was learning how to slope soar. He learned to never turn into the hill!

"I think part of your problem (with Penumbra.2) relates to the fact that you have a foam and fiberglass structure. I prefer open structures of balsa with a translucent covering because its so beautiful against the sky. I've never considered foam and opaque skin until now. So here comes a bunch of random thoughts about skin/foam structure.

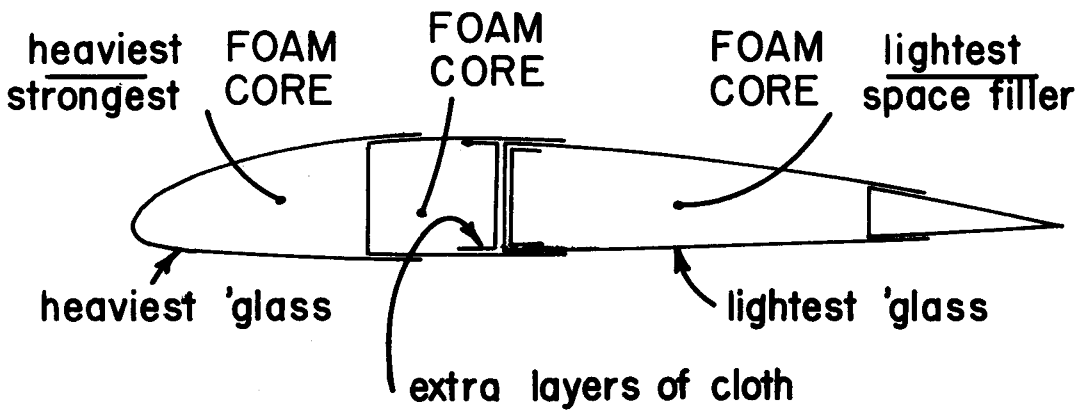
"When a wing deflects in bending the tip rises with respect to the root. The top surface is in compression and the bottom surface is in tension. When a beam deflects under load it tends to deflect in a manner to relieve the load. In a wing the top surface and the bottom surface want to deflect towards one another to decrease the depth of the beam. This reduces the strength of the beam so it can deflect to relieve the load.

"The tensile and compressive strength of fiberglass is about 200,000 lbs./in^2 until it buckles. The strength of foam is only about 1/1000 the strength of fiberglass. I really don't think the fiberglass even knows the foam is there.

"My first thought was to cut the foam core along a given percent chord from root to tip and put in a shear web. Vertical grain balsa of course. Balsa is 10 times stronger than foam (and 10 times heavier) but it's still not nearly as strong as fiberglass, so it isn't quite what we want. I think fiberglass shear webs would be the way to go if the vertical column strength is sufficient and if the web is fastened to the upper and lower skins with a strong joint.

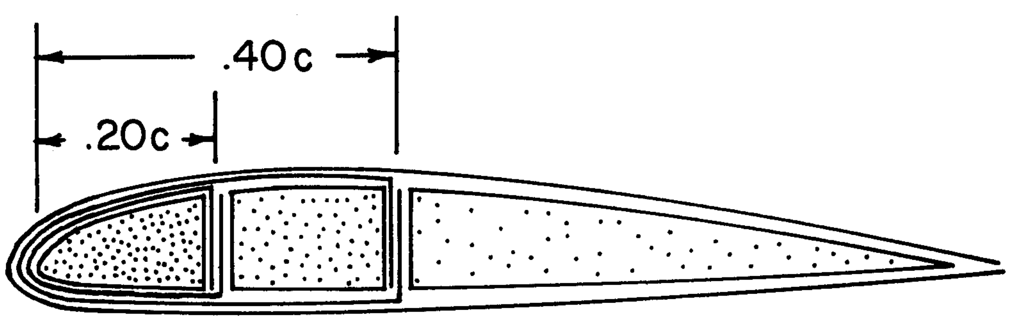


"Take a look at a Rutan Vari-EZE some time.



"The important thing to remember is that the shear web have sufficient strength to carry the compression loads tending to make the top and bottom surfaces touch."

An additional construction method using foam core(s) and fiberglass was described by Bill in a recent 'phone conversation. This is a vacuum bagged structure which provides both strength and mass in the forward portion of the wing. It is brobably similar to what some of you are doing already regarding formation of the D-tube, but the formation of the box spar is a noticeable improvement.



AN ALTERNATE, and stronger, METHOD

In response to all of this information, we're redesigning the entire Penumbra structure. The major changes are as follows:

(1) The spar system will be strengthened and moved forward, and unidirectional fiberglass cloth will be used to increase spanwise rigidity.

(2) One layer of bidirectional fiberglass will be placed with grain at 45 degrees to the wing's leading and trailing edges in an effort to increase torsional rigidity.

(3) Rigidity of the control surfaces, particularly the ailerons, will be monitored very closely, as will their own CG.

(4) Servos will be chosen with regard to lack of play at the output shaft, and linkages will be rigid.

We hope that you've gained as much from reading Bill's material as we have. John Borlaug's Counsellor, the canard that Bill mentions in this article, will be described in a future column.