“The Middle Effect”

In the March 1994 issue of *RCSD*, we discussed Dr. Ing. Ferdinando Galè’s Ubara, a swept wing free flight HLG. This model featured a “bat tail,” and a good portion of our column was devoted to an examination of possible effects this configuration might have on performance. Figure 1, which was included in that column, generated the following request from Ted Off, of Ventura California:

“That little ‘throw away’ drawing of the Horten brothers (p. 14, *R/C Soaring Digest*, 3/94) was fascinating. I’ve never seen this idea before. How about more information in your next column?”

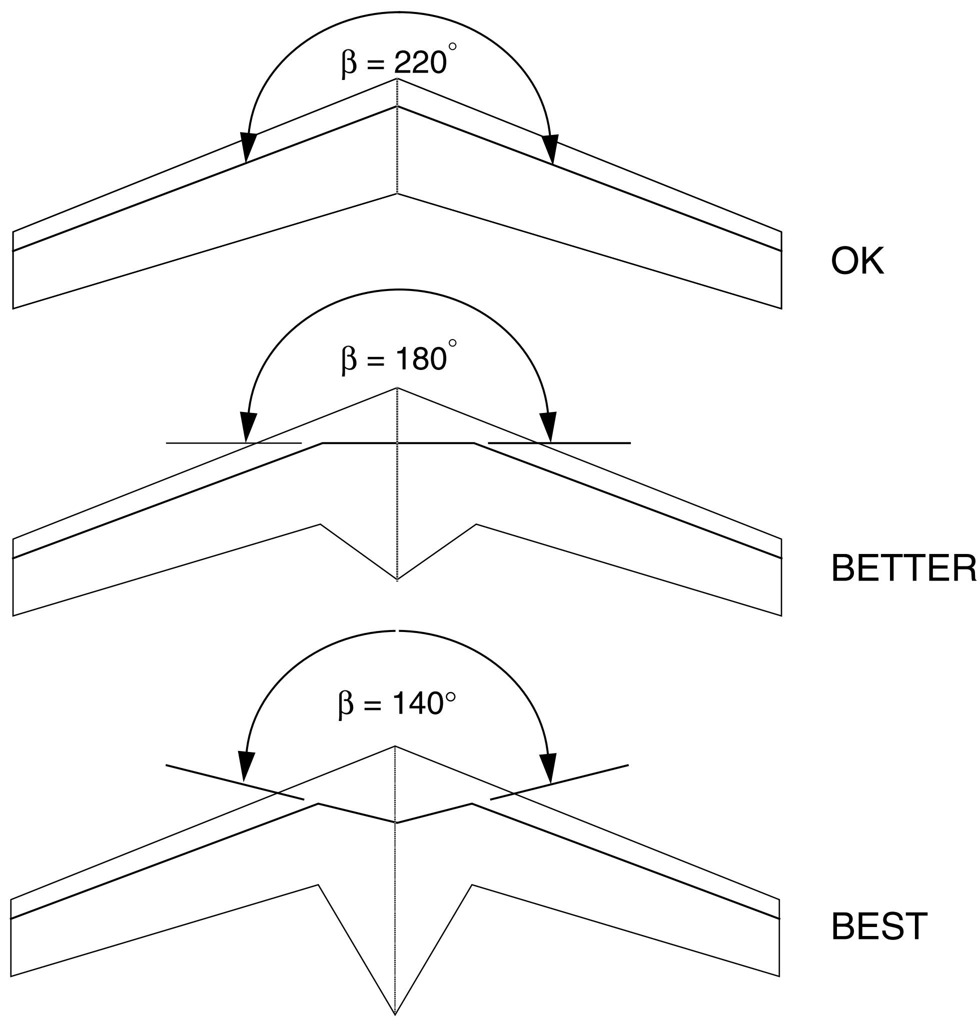
Well, we didn’t get his written in time for the next column. In fact, we’re well into the next year! Hopefully, however, this month’s column will provide the information Ted was requesting.

The “bat tail” or “cuspidate tail,” as it is also known, has been portrayed as a method of compensating for “the middle effect,” defined as a loss of lift at the center of a swept wing.

The proposed reason for this loss of lift is the detrimental interaction of vortices at the center of the wing. The Horten brothers offered a solution to this problem: construct the wing such that the quarter chord lines of the two wing halves meet at an angle of less than 180° at the center line. Refer to Figure 1 to see how this is accomplished. This modification of the quarter chord line is said to change the angle at which the vortices meet, thus inhibiting the adverse action. A side effect of this is an increase in the wing area at the root which gives a proportional increase in lift.

A logical question to be asked is, “How did designers and pilots recognize such a loss of lift at the center section?” The answer is, through flight experience. It was found that even though the CG had been determined by calculating the lift distribution, the resulting aircraft was always nose heavy in flight. To explain this nose heaviness, it was assumed there was a loss of lift at the center of the wing.

Such an aerodynamic explanation turns out to be not correct, however. To find the real reason for the nose heaviness of sweptback wings, it is only

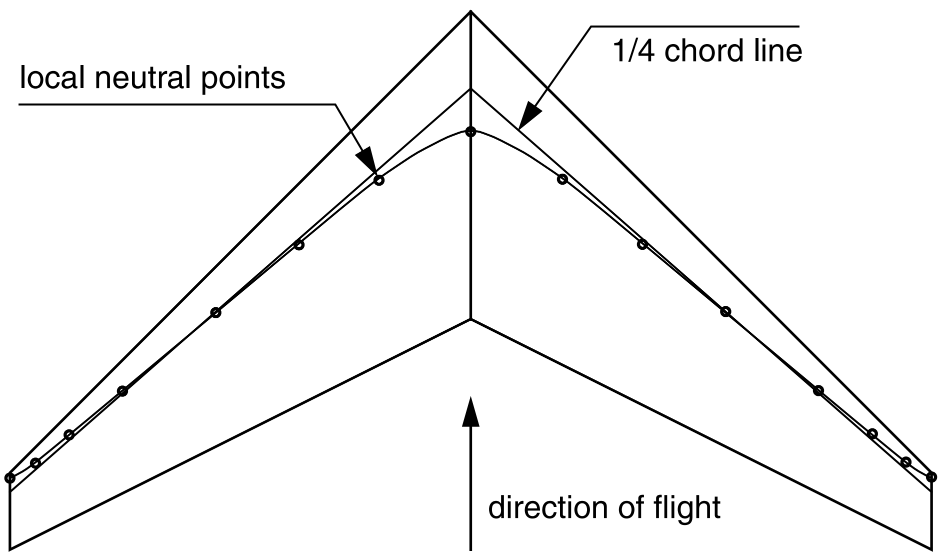


β, the angle at which the quarter chord lines of the two wings meet at the center line, should be less than 180°, according to the Horten brothers.

Figure 1

necessary to look at the method being used for determining the lift distribution.

Figure 2 shows that for a swept back wing, the lines formed by the local neutral points do not follow the quarter chord lines. The local neutral point is aft of the quarter chord line at the center line, and ahead of the quarter



Local neutral point behind quarter chord line at root, ahead of quarter chord line at tip.

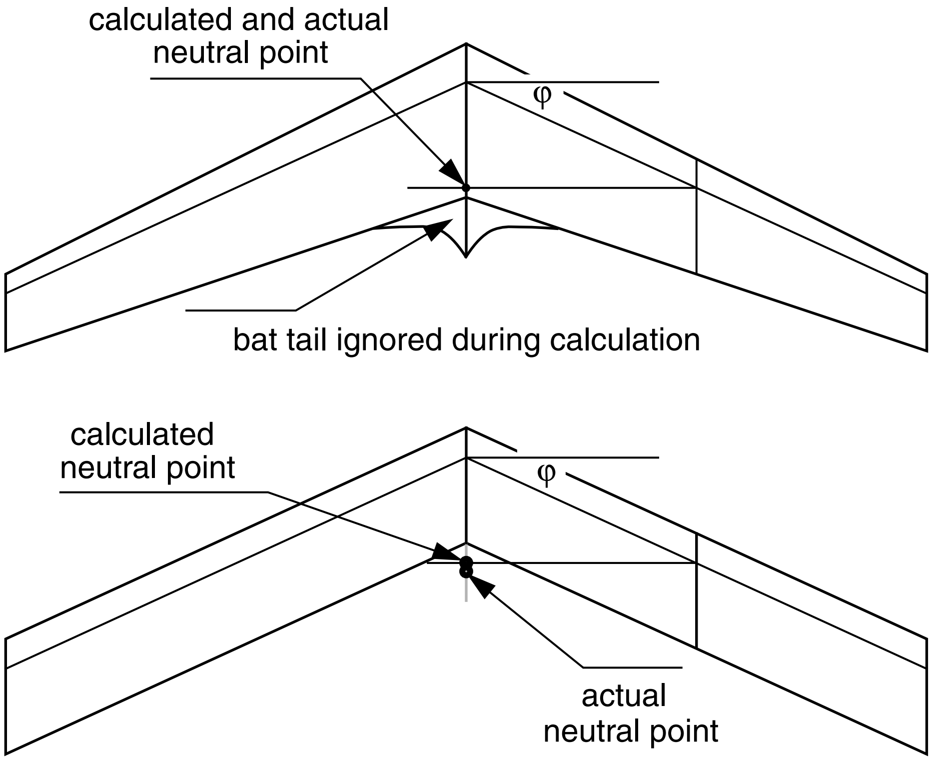
Figure 2

chord line at the wing tip. This is the case for all wings which are swept back. (If the wing is swept forward, the situation is reversed.)

Prior to and during World War II, the lift distribution of swept wings was determined by working out the lift distribution of an "equivalent" unswept wing. That lift distribution was then placed on the quarter chord line of the swept wing. This led to errors, but until about 1950 there was no better way.

This method of calculating the lift distribution predicted too much lift for the center of the wing and too little for the wing tips. The calculated neutral point of the aircraft was therefore forward of the actual location. Since the location of the CG is based on the location of the neutral point, it also was excessively forward, thus leading to a nose heavy condition.

The nose heaviness experienced in flight, then, was not due to any true loss of lift, but rather to errors in the calculation of the neutral point; an aerodynamic phenomenon was erroneously blamed for what was really a mathematical shortcoming. Modern full size swept wing aircraft are designed using computational fluid dynamic methods which can predict the effects of



Sweep angle, φ, as measured at the quarter chord line, is identical in both cases.

Panknin formulae used to determine the location of neutral point.

Figure 3

sweep on the location of the neutral point and so the CG is placed accurately.

We'll complete this month's column with an interesting sidenote.

Our good friend Alan Halleck has been designing and building swept wings for thermal and slope flight for a number of years. His Razer1, an extremely successful design, appeared in this column in May 1991. Alan uses the Panknin formulae to determine both wing twist and CG location. As a reminder, the Panknin formulae determines the location of the CG based upon the (arithmetic) mean quarter chord point and a prescribed stability factor. All of Alan's 'wings are of tapered planform and incorporate a bat tail formed by a proportionally enlarged root section. The bat tail is ignored during computations, yet all of Alan's designs have flown exceedingly well using the CG location determined by the Panknin formulae. In fact, he has consistently found movement of the CG away from the specified location leads to poorer performance.

In direct contrast to this experience, our own swept 'wings, which are of constant chord and do not incorporate a bat tail, have always proven to be slightly nose heavy when balanced according to the Panknin formulae.

Reference:

Nickel, Karl and Michael Wohlfahrt. Tailless Aircraft in Theory and Practice. American Institute of Aeronautics and Astronautics, Washington D.C., 1994. pp. 445 - 447.

Winglets forever!

— Hans-Jürgen Unverferth