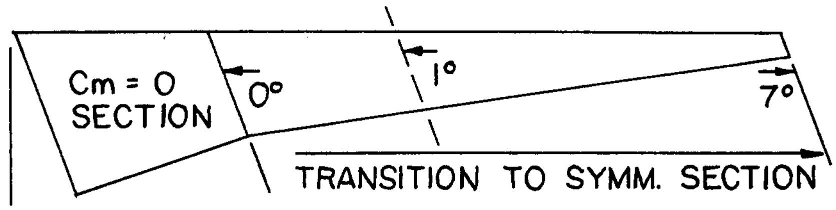
TWIST GEOMETRY FOR SWEPT FLYING WINGS

Swept 'wings can make use of a variety of airfoils, so long as the download at the wingtips counteracts the pitching moment of the lifting surface and provides stability. The wing, therefore, usually incorporates aerodynamic and/or geometric twist, and this month we'll talk about three twist techniques.

To look at the Horten IV or Horten VI is to gaze upon pure beauty. How were the Hortens able to achieve the stability required for flight, much less maneuverability in thermals? Dr. Reimar Horten explains it is a matter of using a root section with no pitching moment, a symmetrical tip section, and the proper amount of twist.[1]

The wing twist method used by the Hortens allows the wing to stall at one third half span, at the location of both center of pressure and center of gravity. This has several beneficial effects: (1) the 'wing can be trimmed easily with small amounts of elevator movement, (2) ailerons remain effective past stalling, and (3) adverse yaw is minimized. With regard this last point: be aware the Hortens used two sets of ailerons and the aileron differential was two way. In a left turn the outboard left aileron went up 20°, the inboard 2° up, the inboard right went down 20°, the outboard 2° down. The ailerons also moved differentially during elevator deflections. Stability and lift distribution were thus maintained during a variety of flight regimes.

The Horten lift distribution can be fairly well duplicated in a model by using the airfoils described above and a total twist of 7°. Build the wing so the first 25% of the half span uses the zero moment section. The remainder of the wing transitions from the root section to a thinner symmetrical section at the wing tip. No twist is used for the first 25% of the half span, one degree is used at the 50% point, and seven degrees is built in at the tip.



If you're constructing with foam, the outer 75% of the half span can be cut in one piece, achieving proper twist and transition of the wing sections at the same time. Using a sufficient number of shims, simply twist the sheet of foam the correct amount in the opposite direction to that needed for the finished wing. Weight it down for cutting. Place the root and tip templates on the ends with no twist relative to the work surface. Once the core is cut the shims are removed and the wing is constructed on the foam beds, as usual. With the beds lying on the flat surface the proper twist is built in!

Model sailplanes using the Horten twist method and keeping the same aspect ratios and taper as the originals will probably suffer from the very low Reynolds number at the wing tips, even in quarter scale. Be aware and beware!

One final thing about the Horten wings - you'll notice some of the Horten designs have "bat-tails". If you plot out the quarter chord line for these designs you'll see it bends and meets the aircraft center line at 90° on the Horten IV, and sweeps forward at the center on the VI. Because of the angle at which the leading edges meet there is a loss of lift in the center section, but the bat-tail is a means of reducing this effect. The lift gradient of the Horten VI compared *favorably with those of conventional* sailplanes.

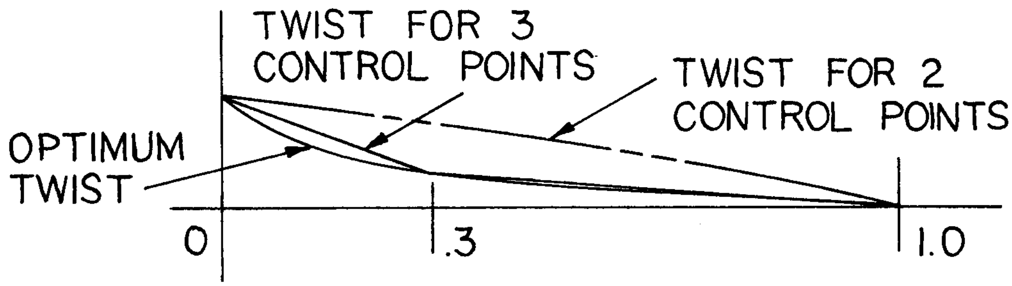
Irv Culver, retired from the Lockheed "Skunk Works", has presented a lift distribution and wing twist method different from that of the Hortens.[2] While the Hortens place the twist toward the wing tips, Culver puts the twist toward the root. The goal here is to reduce induced drag and achieve optimum span loading.

Culver's method is not so simple (!) as that of the Hortens, as it involves a formula which requires that overall design lift coefficient, aspect ratio, sweep angle of half chord line, and zero lift angles of the sections used be known and specified.

$$\alpha^{\circ}_{RT} = C_{LD} \cdot \beta^{\circ}_{\frac{1}{2}c} \cdot \pi \cdot \left(1 - \frac{1}{AR+1}\right) \cdot \frac{1}{\left(\frac{2\pi}{1+\frac{2}{AR}}\right)}$$

$$\alpha^{\circ}_{S} = \alpha^{\circ}_{RT} \cdot (1 - STA)^{\frac{AR+2\pi}{2\pi}}$$

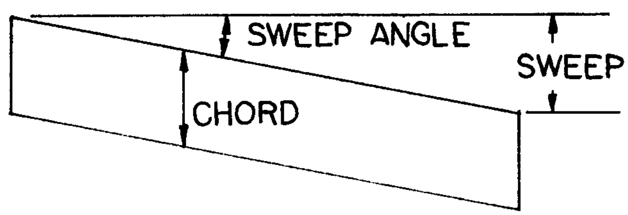
Typically, Culver's method relies on three control points - root, 30% half span, and tip.



The twist configuration advocated by Culver is easily accomplished with foam core construction, a definite advantage. Also, if a section with high coefficient of lift is chosen, trimming for high speed can still be acomplished with deflection of tapered elevons. The disadvantage is adverse roll-yaw coupling - there is excessive roll when the aircraft is yawed. The solution is to bend the wing tips down, as seen on some of the Northrop 'wings.

QBE is the third method of achieving correct wing twist. QBE stands for Quick But Effective. Cutting the foam core wings couldn't be easier: align wing root template at 0°, set up the wing tip template at the predetermined angle, and cut the foam. A wing half can be cut in one piece with straight taper and straight twist built in. The real secret is in determining what angle to use when aligning the wing tip template on the foam.

There is a formula, based on zero lift angles, moment coefficients, sweep ratio, and a stability factor (see OTW #5, "Computer Programs for Determining Sweep and Twist), but here are a few suggestions from designs which fly well: (1) Eppler 174 root, Eppler 182 tip, constant chord, wing swept 1.5 chord lengths measured at the tip, 4° twist;
(2) Eppler 180 root, Eppler 184 tip, aspect ratio of 9.1, 20° leading edge sweep, 1° twist; (3) Eppler 222 root, Eppler 230 tip, constant chord, wing swept 1.5 chord lengths measured at the tip, 0°; and (4) Eppler 224 root, Eppler 230 tip, constant chord, wing swept 1.1 chord lengths measured at the tips, 0° twist.[3]



All through the above discussion we've talked about foam core construction - because it's both accurate and fast. Foam core construction promotes rapid design evolution. Experiment and share your findings with others!

1. The bulk of this information came from an article by Jan Scott of the Vintage Sailplane Association, originally published in The Bungee Cord, and from Dr. Martin Lichte's book "Nurflugelmodelle". Additional information can be found in TWITT Newsletter #10.

2. TWITT Newsletter #4.

3. For further information, see MTB (Modell-Technik-Berater) 1/2; these were originally published separately, but are now under one cover; available directly from the publisher: Verlag fur Technik und Handwerk GMbH.

CULVER TWIST DISTRIBUTION

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10     PI = 3.141592654
100    PRINT "Enter the design lift coefficient": INPUT CL
200    PRINT "Enter the wing's aspect ratio": INPUT AR
300    PRINT "Enter the sweep angle of the half chord line, in
       degrees": INPUT SA
1000   X = 1 / (AR + 1):Y = (2 * PI) / (1 + (2 / AR)):TA = CL *
       SA * PI * (1 - X) * (1 / Y)
1200   PRINT TA
1500   FOR ST = 0 TO 1 STEP .1
2000   Z = (AR + (2 * PI)) / (2 * PI):AS = TA * ((1 - ST) ^ Z)
2250   PRINT ST,AS
2500   NEXT ST
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