COMPUTER PROGRAMS FOR DETERMINING SWEEP AND TWIST

There are three general types of tailless sailplane:

(1) the "plank," usually with leading and trailing edges parallel, or nearly so, and a central vertical fin,

(2) the swept wing, with either a single fin centrally located on a boom or one fin at the end of each wing, and

(3) the true "flying wing" which is a swept wing with no vertical surface at all.

We've been flying planks for several years, and most people are shocked to find there is no twist in the wings to provide stability. The airfoils used on planks are self stabilizing and accomplish this through a reflexed trailing edge. Simply put, the CG is located more forward than on a conventional design, and the upturned trailing edge applies the down force normally exerted by the horizontal stabilizer. The plank, then, is nothing more than a conventional sailplane with the stabilizer built into the wing itself rather than hanging on a boom. Dave Jones' "Raven" design, which we've been flying, will actually be DEstabilized if twist is incorporated into the wing.

Swept wing tailless and true flying wings, however, use twist to achieve stability. Sometimes this is accomplished with an actual physical twist being built into the structure. Other times, if the airfoils are chosen carefully, the twist can be accomplished aerodynamically, and the wing built with no geometric twist at all.

The amount of twist required is based on four things:

(1) the moment coefficients of the root and tip airfoils,

(2) the zero lift angles of the two sections,

(3) the degree of sweep, and

(4) the amount of stability desired.

The obvious question is, "If I know these four things, can I calculate the geometric twist required for my design?" As a matter of fact, yes, you can. You can even do something a little different, too. If you know how much geometric twist you want to use, you can calculate how much sweep your design will need! How about that!

The formulae for these routines were found in two different places: in an article entitled "Pfeilung - ja - aber wie gross" ("Arrowshape - yes - but how large") by the late Werner Thies and published in Flug + modelltechnik (FMT) in the February, 1984, issue, and in the book "Nurflugelmodelle," authored by Martin Lichte. The equations are different in appearance but are mathematically equivalent. The routines printed here are derived from the FMT article and assume swept wings with no taper and either foam core wings or stack sanded ribs for construction.

There are a few generalizations that may help you better understand the routines.

(1) An undercambered root section will need more wing twist than a semisymmetrical root section when using the same tip section,

(2) the higher the sweep ratio the less twist is required,

(3) more twist equates with greater stability because the CG must be moved forward to trim, and

(4) the twist itself can come from either geometric twist (physical warping) or aerodynamic twist (difference in zero lift angles of the sections).

Two terms need further explanation. The sweep ratio (SWEEPRAT) is defined as the number of chord lengths from the leading edge of the root to the leading edge of the wing tip (see diagram). The stability factor (STABFAC) is a number usually in the range of 0.02 to 0.04, the larger number correlating to greater stability. You'd probably want 0.04 for a stable floater or trainer, and 0.02 for a highly aerobatic sloper or very sensitive F3B 'ship.

These routines can be expanded very easily with a little knowledge of BASIC. Placing the airfoil data in random access text files on disk or in DATA statements is a good start, and sailplane design programs using high resolution graphics are also a possibility.

Don't be afraid to experiment! Using the same airfoils and sweep ratio, manipulate the stability factor and watch the required geometric twist change. When the result is positive the tip is set to a lower angle of attack than the root. You would usually not want to see a negative number here if using sweepback. Or use a different root section and see how much more or less sweep is required to remain at a particular level of stability. A positive number here means sweepback. Try to keep the sweep ratio not too much bigger than two, otherwise severe tip stalling may result from cross span flow. Watch for "DIVISION BY ZERO ERROR" messages.

Just to get you started, we figured the twist required for Curt Weller's Elfe 2 (see the diagram again). This tailless design has a sweep ratio of 1.54 based on the mean (average) chord length, with an Eppler 180 at the root and Eppler 184 at the tip. The computer tells us that for a stability factor of 0.02 the wing twist should be about zero degrees; with a stability factor of 0.03 the twist should be about 1.2 degrees. The Elfe 2 uses one degree of twist to compensate for wing taper and inhibit the tips from stalling before the root. As Curt is a former F3B champion in Austria and has used the Elfe 2 in competition, you now have a little better idea as to the meaning and use of the stability factor.

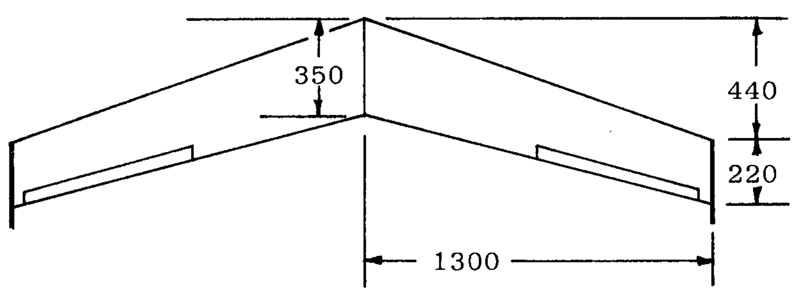
We hope you find these routines useful when designing your own tailless creations. If you don't have a computer, a calculator works just fine, too.

Some airfoil data for use in the routines:

Section	Moment Coefficient	Zero Lift Angle
Eppler 174	-0.083	-3.6
" 176	-0.06	-2.79
" 178	-0.038	-1.97
" 180	-0.016	-1.12
" 182	0.007	0.3
" 184	0.03	0.52
" 186	0.05	1.14
" 222	-0.0974	-3.65
" 224	-0.0613	-2.33
" 226	-0.0231	-0.99
" 228	0.0143	0.34
" 230	0.0531 *	1.73

* Dr. Walter Panknin recommends the use of 0.025 in place of this published value.

to find sweep ratio:
mean chord = (350 + 220)/2
= 285
SWEEPRAT = 440/285 = 1.54



Zero Lift Angles	=	ZROOT, ZTIP
Moment Coefficients	=	MROOT, MTIP
Stability Factor	=	STABFAC
Sweep Ratio	=	SWEEPRAT
Aerodynamic Twist	=	AEROTWIST
Geometric Twist	=	GEOTWIST
Total Twist	=	TWIST

```
10000  REM ** TWIST ROUTINE **
10010  CM = (MROOT + MTIP) / 2 :
       REM * AVERAGE MOMENT COEFFICIENT
10020  TWIST = (190 * (STABFAC - CM)) /
       SWEEPRAT : REM * TOTAL TWIST
10030  AEROTWIST = ZTIP - ZROOT :
       REM * AERODYNAMIC TWIST
10040  GEOTWIST = TWIST - AEROTWIST :
       REM * GEOMETRIC TWIST REQ'D
10050  REM ** BUILD WITH GEOTWIST **
```

```
20000  REM ** SWEEP ROUTINE **
20010  CM = (MROOT + MTIP) / 2 :
       REM * AVERAGE MOMENT COEFFICIENT
20020  AEROTWIST = ZTIP - ZROOT :
       REM * AERODYNAMIC TWIST
20030  TWIST = GEOTWIST + AEROTWIST :
       REM * TOTAL TWIST
20040  SWEEPRAT = (190 * (STABFAC - CM)) /
       TWIST : REM * SWEEP RATIO
20050  REM ** BUILD WITH SWEEPRAT **
```

THIES SWEEP AND TWIST

```
10    REM   COMPUTES SWEEP RATIO
20    REM   WHEN NO TWIST IS USED
30    TEXT
40    HOME
50    PRINT "SWEEP RATIO"
60    PRINT "----- -----"
70    FOR X = 0 TO 2000: NEXT X
80    HOME
90    PRINT "Enter the Stability Factor desired"
100   PRINT "(Usually 0.02 to 0.04)        ": INPUT SF
110   PRINT "Enter the Moment Coefficient of the rootsection":
      INPUT M1
120   PRINT "Enter the Zero Lift Angle of the root   section":
      INPUT Z1
130   PRINT "Enter the Moment Coefficient of the tip section":
      INPUT M2
140   PRINT "Enter the Zero Lift Angle of the tip    section":
      INPUT Z2
150   DZ =  - Z1 + Z2
160   CM = (M1 + M2) / 2
170   SR = (190 * ( - CM + SF)) / DZ
180   PRINT "Sweep Ratio = ";SR
190   PRINT : PRINT "Another sweep ratio? ";: GET A$: IF A$ <  >
      "Y" AND A$ <  > "N" THEN  HOME : GOTO 190
200   IF A$ = "Y" THEN  GOTO 80
210   IF A$ = "N" THEN  TEXT : HOME : END
220   REM  COMPUTES TWIST
230   REM  BASED ON
240   REM  SWEEP RATIO
250   TEXT
260   HOME
270   PRINT "TWIST"
280   PRINT "-----"
290   FOR X = 0 TO 1000: NEXT X
300   HOME
310   PRINT "Enter Sweep Ratio": INPUT SR
320   PRINT "Enter Stability Factor"
330   PRINT "(usually 0.02 - 0.04)        ": INPUT SF
340   PRINT "Enter the Moment Coefficient of the rootsection":
      INPUT M1
350   PRINT "Enter the Zero Lift Angle of the root   section":
      INPUT Z1
360   PRINT "Enter the Moment Coefficient of the tip section":
      INPUT M2
370   PRINT "Enter the Zero Lift Angle of the tip    section":
      INPUT Z2
380   CM = (M1 + M2) / 2
390   TWIST = (190 * ( - CM + SF)) / SR
400   NULL =  - Z1 + Z2:SCHRANK = TWIST - NULL
410   IF SCHRANK > 0 AND SCHRANK < .001 THEN SCHRANK = 0
420   IF SCHRANK < 0 AND SCHRANK >  - .001 THEN SCHRANK = 0
```

```
430  IF SCHRANK = 0 THEN  GOTO 460
440  PRINT "Final twist = ";SCHRANK;" Degrees"
450  GOTO 470
460  PRINT "Final Twist = 0.0 Degrees"
470  PRINT : PRINT "Another combination? ";: GET A$: IF A$ <  >
     "Y" AND A$ <  > "N" THEN  VTAB (15): GOTO 470
480  IF A$ = "Y" THEN  GOTO 300
490  TEXT : HOME : END
```