On the ’Wing... #127

Walter Panknin’s Flying Rainbow

In 1989 we travelled to Madison Wisconsin to attend our first MARCS Symposium. As several previous Symposiums had featured Ken Bates speaking about his numerous flying wing experiments, we were hoping that the 1989 gathering would be no different. Prior to the event, we learned that Dr. Walter Panknin was on the Symposium agenda, scheduled to speak about his "Flying Rainbow" design.

A brief description of Dr. Panknin’s presentation at the Symposium appeared in “On the ’Wing...,” and a complete transcript of Walter’s presentation ia available from the Madison Area Radio Control Society. Walter did not focus an any particular aspect of his Flying Rainbow, but rather provided a generalized overview of swept wing tailless design.

It took several years of friends’ prodding to convince Walter to build his first “flying wing.” Günther Koech, an aircraft designer employed by Lippisch during WWII, was a proponent of the idea, along with Hansjörg Ackerman, a pioneer in building tailless models. But it was a paper by Helmut Schenk, “Determination of the Longitudinal Moment for the Flying Wing Model,” which served as motivation for Walter to build his first ’wing. Schenk’s paper explained how the moment coefficients and zero lift angles of the airfoils worked in conjunction with wing twist, sweepback, and other variables so as to achieve a pitch stable aircraft.

A fundamental formula which Schenk provided in his paper served to integrate these important variables, and while it looks intimidating, it is actually relatively simple. A low-cost scientific calculator makes quick work of evaluating a single design, and computer programs have been written which allow iterative processes and user manipulation of one or several variables.

The Schenk formula is:

$$\alpha_{total} = \frac{(K_1 \cdot C_{Mi} + K_2 \cdot C_{Ma}) - \overline{C_L} \cdot St}{1.4 \cdot 10^{-5} \cdot \lambda^{1.43} \cdot \Lambda}$$

where

b	= wing span
t_i	= root chord
t_a	= tip chord
t_m	= (ta + ti)/2
l	= aspect ratio, b/tm
L	= angle of sweepback, measured at 25% chord
C_{Mi}	= moment coefficient, root section
C_{Ma}	= moment coefficient, tip section
$\overline{C}_L$	= design coefficient of lift, $C_{Lcruise}$
St	= stability value (static margin)
t	= taper ratio, ta/ti

Dr. Walter Panknin (front row, third from left) and his “Flying Rainbow”

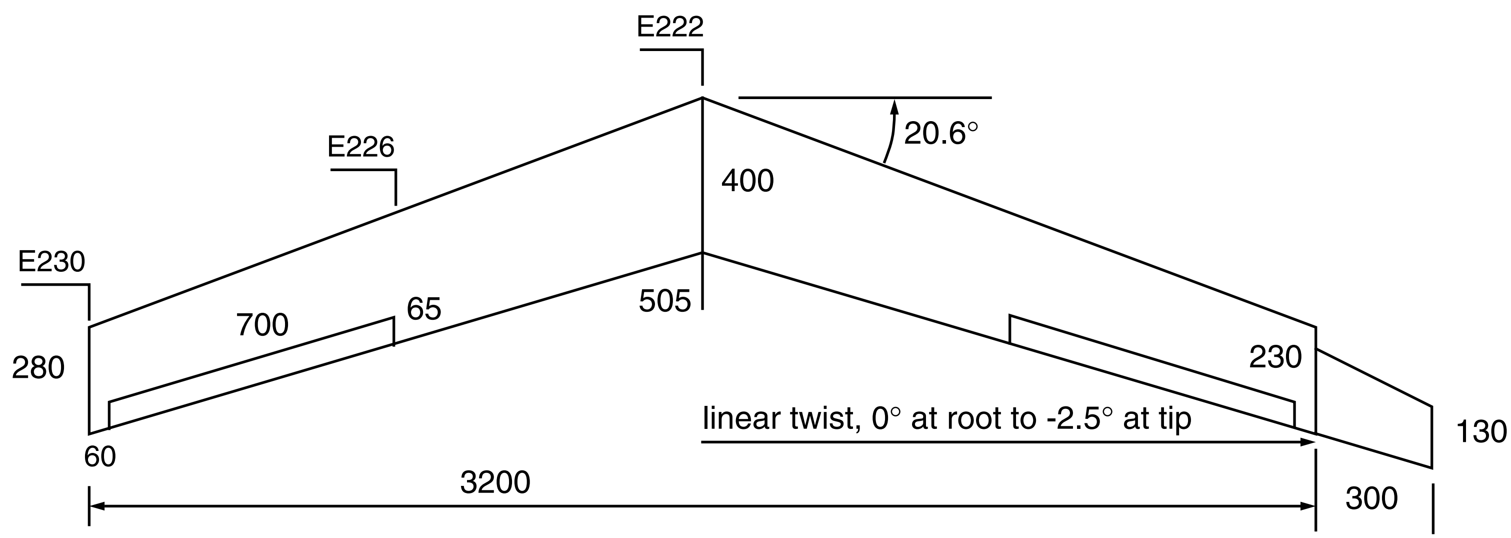
K_1 $= 1/4 \cdot (3 + 2t) + t^2)/(1 + t + t^2)$
K_2 $= 1 - K_1$

and

$$\alpha_{geo} = \alpha_{total} - \left(\alpha_{0L_{root}} - \alpha_{0L_{tip}}\right)$$

where
α_{geo} = geometric twist, used when cutting cores
$\alpha_{0L_{root}}$ = zero lift angle, root section
$\alpha_{0L_{tip}}$ = zero lift angle, tip section
α_{total} = total wing twist, aerodynamic

To use the Schenk formula, the designer must always begin with knowledge of the pitching moment, C_{M0}, and zero lift angle, $a_{L=0}$, of the airfoil(s) used at the wing root and tip. Changing airfoils, taper ratio, aspect ratio, sweepback and static margin gives the designer wide latitude so far as final design. A comprehensive examination of the dynamics of the Schenk formula was published in *RC Soaring Digest* a few years ago.



DR. WALTER PANKNIN'S "FLYING RAINBOW"

Wingspan	3.20 meters	Aspect Ratio	9.4
Root Chord	400 mm	Tip Chord	280 mm
Keel Length	505 mm; extends from trailing edge to act as hand hold		
Wing Area	109 dm^2	Sweep; LE, t/4	20.6, 19.6 deg
Wing Loading	33 g/dm^2	Geometric Twist	-2.5 deg
Fin Root	230 mm	Fin Tip	130 mm
Winglet Area	2 * 93 in^2	Winglet Height	300 mm
Profiles	E222, E226, E230		
Elevons	65 mm x 700 mm, outer end 60 mm from wing tip		

The planform of Walter's "Flying Rainbow" was determined using Schenk's formula. We've spent some time at the computer and have been able to work backward from the final design to determine some of the initial parameters. This "Flying Rainbow" uses the Eppler 222 at the root and the E 230 at the tip. The zero lift angles are $\alpha_{0L_{root}}$ = -3.65 and $\alpha_{0L_{tip}}$ = +1.73, respectively. Plugging the latter values into the second formula,

$$-2.5 = \alpha_{total} - (-3.65 - 1.73)$$

$$\alpha_{total} = -2.5 + (-3.65 - 1.73)$$

$$\alpha_{total} = -7.88\text{degrees}$$

For Walter's Flying Rainbow, we also know the following information:

b	= 3200 mm, 126.3"
t_i	= 400 mm, 15.8"
t_a	= 280 mm, 11.0"
t_m	= (280 mm + 400 mm)/2 = 340 mm
l	= 3200 mm/340 mm = 9.4
L	= 19.6
C_{Mi}	= -0.097
C_{Ma}	= +0.025*
t	= 280 mm/400 mm = 0.7
K_1	= 1/4 · (3 + 1.4 + 0.49)/(1 + 0.7 + 0.49) = 1/4 · (4.89)/(2.19) = 0.5582
K_2	= 1.0 - 0.5582 = 0.4418

* This value was derived by Dr. Panknin based on practical experience and a formula utilizing the camber line leading edge and trailing edge angles.

The primary formula, once appropriate values are inserted, becomes:

$$-7.88 = \frac{(0.5582 \cdot -0.097 + 0.4418 \cdot 0.025) - (\bar{C}_L \cdot St)}{1.4 \cdot 10^{-5} \cdot 9.4^{1.43} \cdot 19.6}$$

$$-7.88 = \frac{(-0.043) - (\overline{C_L} \cdot St)}{0.0068}$$

$$(-7.88 \cdot 0.0068) + 0.043 = -(\overline{C_L} \cdot St)$$

$$\overline{C_L} = \frac{0.0106}{St}$$

Based on planform geometry and actual CG location, and using the iterative abilities of our computer program, we set St = 0.075 and find:

$$\overline{C_L} = \frac{0.0106}{0.075}$$

$$\overline{C_L} \cong 0.14$$

The elevons should be set for no deflection during cruise. That is, the elevons should be set such that they are in trail. This setting will produce the lowest drag. Additionally, when trimmed in this way, the aircraft should be operating at L/D_{max}. $\overline{C_L}$ = ~0.14 is, therefore, not an unreasonably low value.

From a structural point of view, Walter’s "Flying Rainbow" included some rather unique solutions to the inherent difficulties of swept wings.
The spar, for instance, is built around a 5/8" by 5/8" O.D. square aluminum extrusion. The spar caps are made by laying 0.125" by 5/8" spruce strips on top of and under the aluminum box. To minimize the effect of the transition from the aluminum to the balsa sheer web, one of two methods have been used. (1) The sheer web between the spruce strips is balsa with 1/16" plywood sides transitioning to balsa near the end. (2) The use of carbon fiber over the spruce cap strips can be used to reduce the stress riser at the end of the aluminum tube without the use of 1/16" plywood and balsa. The spar runs to the leading edge of the cores near the end of the center panels. The joiner rod can be 0.5" steel, aluminum, fiberglass or carbon fiber rod.

Further reinforcement is required if balsa sheeting is to be used as the wing skin. For purposes of torsional stiffness, some glass cloth should be placed on the core at a 45 degree angle. An alternative would be to use carbon fiber veil to increase the torsional stiffness.

Winglets are made from blue foam with a balsa base. The installation of wood blocks for mounting the winglets should be considered before sheeting. The objective is to keep them light. Walter used pressure sensitive plastic film (vinyl shelf lining paper) to cover them, and this worked out very nicely. The weight of the winglet should not exceed 35 grams or 1.2 ounces. This weight requirement can also be met by using blue foam with 2 oz. cloth vacuumed bagged onto it.

Walter used a third servo mounted in the wing root to control a flap which was hinged at about 50% of the 3" flap chord. The flaps were about 10" long on each side. This setup serves as more of a speed brake than a flap, and no pitching results from its use.

The "Flying Rainbow" is an extremely successful design. It builds rapidly, can be winch launched, is stable, and performs well both over flat land and on the slope. Interestingly, it seems to do better in turbulent conditions.

Walter’s presentation at the MARCS Symposium was not only exciting, it provided the motivation for us to begin construction of our own series of swept wing tailless sailplanes — Project Penumbra. Walter visited us in April 1991, and we spent a day at 60 Acres testing and trimming one of the later versions. His death in November 1992 affected us deeply, and we dedicated “On the ’Wing... the book” to his memory.

References:

Dr. Walter Panknin at the MARCS Symposium. “On the ’Wing...,” *RC Soaring Digest*, September 1990, and “On the ’Wing... the book,” pp. 106 - 107.

“Flying Rainbows. Proceedings of the 1989 National Sailplane Symposium. Al Scidmore, Editor.

Four Basic Concepts. *RC Soaring Digest* October 1994 through January 1995, and “On the ’Wing... the book, Volume 2,” pp. 73 - 93,

Panknin.bas is available in Applesoft BASIC, and in QuickBASIC for both IBM-compatibles and the Macintosh platform. Alan Halleck’s Razer1 and Dr. Panknin’s Twist Formulae, “On the ’Wing... the book,” pp. 132 - 141, and <http://www.b2streamlines.com/Panknin.html>.

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