On the ’Wing... #149

Using the Panknin formulae to choose a plank airfoil

Craig Coles, a plank planform enthusiast, wrote to us a while back, inquiring about control surface location as related to various tailless planforms. The ensuing column, completed after nearly five years of languishing as a “work in progress,” appeared in *RCSD* a few months ago. Craig then responded with a few questions concerning how to choose an airfoil for a plank planform, and this column is the result. We’ll never be in want of subject matter for future columns if Craig can just keep this routine going.

Craig’s questions were all related to the required pitching moment for a plank planform which is currently in the design process. He had been leaning toward one of the EH series, but then took a look at some of the MH sections in the 40 and 60 series, noting that these were designed for flying wings.

The EH sections, which we’ve several times promoted within this column, have positive but near zero pitching moments. They have been used on swept wings, deltas, and, surprisingly, on planks as well. The Zipper, put out by The Bird Works in Port Orford Oregon, uses the EH 2.0/10.0 and flies extremely well on the slope. Flying speed (and pitch stability) is directly related to elevator trim. It is capable of flying at very high speed in good lift and can stay up in the light stuff, too.

The MH sections, on the other hand, were designed for swept wings and several have slightly negative pitching moments. Some amount of wing sweep and twist is necessary for pitch stability when using the sections with negative pitching moments, and so they cannot be used on plank planforms without a significant amount of up trim from trailing edge control surfaces. The MH sections with low positive pitching moments can be used on planks in exactly the same manner as the EH sections mentioned above. The MH 46 and 49 have substantial positive pitching moments, +0.03 and greater than +0.04 respectively, and can be used on planks when larger amounts of stability are desired.

So long as the center of gravity is forward of the neutral point, some amount of positive pitching moment is required to make a plank planform stable in pitch. In choosing an airfoil for a plank planform, therefore, the question becomes a matter of determining how much positive pitching moment is needed for pitch stability and specific coefficients of lift. Craig’s primary question was, “Can we use the Panknin formulae to determine the amount of pitching moment needed for a plank planform?”

Joa Harrison wrote an Excel spreadsheet template for the Panknin formulae a few years ago, and it remains available on our web site on the Panknin page. The spreadsheet is set up so that changes to the various parameters automatically update the “geometric twist” cell, so you can immediately see the effects of any changes.

To demonstrate the pitching moment required for various flight regimes, we set up a very simple “generic” plank planform with a constant chord wing. The various parameters are listed in Table 1. Because plank planforms utilize the same airfoil across the entire span, the section zero

Table 1: Generic plank planform

Parameter	Dimension
Span	100 inches
Root chord	10 inches
Tip chord	10 inches
Sweep angle	0.25 degrees
Zero lift angle, root	zero degrees
Zero lift angle, tip	zero degrees
Static margin	0.03, 0.05 (variable)
Coefficient of lift	0.25, 0.42, 0.60 (variable)

lift angles can be set to any consistent value. For simplicity, we used zero. Be sure to plug in identical pitching moment values for both the wing root and wing tip sections. Note also that there is a very small amount of sweep in the wing. That's because the Panknin formulae can not handle zero sweep situations — there will be a division by zero error, indicating that the twist required will be infinite. Using a sweep angle of one quarter of one degree eliminates this difficulty, but makes the geometric twist value very sensitive to changes in the pitching moment value(s). Changes in the pitching moment of just 0.001 equate to several degrees of twist.

On Joa's spreadsheet, we first plugged in all of the constants, then went about finding the pitching moment value for both the root and the tip which would set the required twist to zero. This was somewhat difficult, as we explained before, because the small sweep angle magnifies the twist values, so any twist value within one degree of zero was considered acceptable. Through an iterative process of approximation, we developed the pitching moment values enumerated in Table 2. As would be expected, the required pitching moment increases along with increases in the coefficient of lift and a larger static margin.

In light of the information in Table 2, let us reiterate what we said previously about the EH and MH sections Craig was looking to use.

The very small positive pitching moments of the EH sections are not very strong, but are sufficient for flying at high speed, that is at a coefficient of lift of around 0.1 or lower. Very small amounts of up elevator trim are sufficient to increase the pitching moment such that the angle of attack increases and the airfoil is capable of higher lift. The positive pitching moment limit occurs when the airfoil stalls or the up elevator trim produces so much down force that the overall lift of the airfoil becomes zero.

The MH sections which have slightly negative pitching moments can not be used on non-swept wings unless sufficient up trim is imparted that the pitching moment becomes positive. The

designer is better off picking a section with some amount of reflex built in, such as the MH 60, MH 61, or MH 45. These sections have small positive pitching moments and can be trimmed for

Table 2: Required pitching moment

C_L	Static margin	Required C_M
0.25	0.03	0.0074
	0.05	0.0123
0.42	0.03	0.0125
	0.05	0.021
0.60	0.03	0.018
	0.05	0.030

various flight regimes much like the EH sections. The MH 46 and 49 have substantial amounts of reflex and therefore have relatively large positive pitching moments.

As a final note, we've built a large number of planks over the years, and have considered the CJ sections to be too stable for our flying style. Despite their popularity, most of the CJ sections have pitching moments of around 0.02 to 0.03 and above, which is too much in our opinion. The excessive reflex built into them is a source of unwanted drag and requires a more forward CG, which further detracts from performance, and small amounts of down trim for effective cruising between thermals. The MH 46 and MH 49 may be in this same category. We would prefer using sections with a lower positive pitching moment. Applying a small amount of up trim while thermalling and reverting to neutral trim for moderate speed when coming back from downwind is our ideal.

We very much encourage anyone designing a plank planform to utilize Joa's s Excel spreadsheet and spend some time manipulating variables and looking over some airfoil polars. Minutes of effort during the design process can yield substantial returns in the form of better flying performance.

Thanks again to Craig Coles for being the impetus behind another column. You, too, can be influential in determining the subjects of future "On the 'Wing..." columns. Send your suggestions to us at P.O. Box 975, Olalla WA 98359-0975 USA, or <bsquared@halcyon.com>.

Reference notes:

Information on the Panknin formulae, including Joa Harrison's spreadsheet and BASIC code for both Macs and DOS, is available on our web site at <http://www.b2streamlines.com/Panknin.html>.

Coordinates for the EH sections can also be found on our web site at <http://www.b2streamlines.com/EH.html>. Polars for the EH sections can be found on Michael Selig's web site through <http://amber.aae.uiuc.edu/~m-selig/flyingWingAfs/>.

Coordinates and polars for the MH sections (except the MH 49) can be found on Martin Hepperle's site at <http://members.tripod.de/MartinHepperle/Airfoils/>. (As this is being written, Martin is in the process of moving his site to a new server, so this URL may differ from what *RCSD* readers have previously bookmarked in their web browsers.)

Those wishing to have a better understanding of the Panknin formulae and the relationships between sweep, static margin, pitching moment coefficient, the design coefficient of lift, and required twist may find it helpful to revisit our "On the 'Wing..." columns of October 1994 through January 1995, "Four Basic Concepts." Additionally, our August 1996 column, "Sections With Near Zero Pitching Moments — Good Choices for Plank Planforms," is a good parallel to this month's article. Both of these items are available in "On the 'Wing... the book, Volume 2."

The Zipper is available from Steve Hinderks at The Birdworks, P.O. Box 1302, Port Orford OR 97465, <http://www.harborside.com/~birdworks/bwhome.htm>, <birdworks@harborside.com>.