On the 'Wing... # 171b

BW 05 02 09 revisited

We first learned of the BW 05 02 09 section when we found it as an alternative airfoil on the plans for Dave Jones Raven S. We scanned the best of the outlines, then used the coordinate creation function of Gregory Payne's Foil 1.2 to obtain the basic coordinate table. We've now used the airfoil on a number of aircraft with chord lengths ranging from five to 27 inches and have found its performance to be downright exceptional. The pitching moment is less than that of the CJ-25^{2}09, and it is definitely more "slippery," both of which are gross improvements. As we're going to use the BW 05 02 09 on another project, we decided to take a look at how smooth the contour of our plotted sections had turned out to be.

We now use Dave Johnson's MacFoil 1.5 for all of our airfoil plotting. MacFoil does not use a spline to smooth the contour but rather draws straight lines between coordinate points. This is OK for most model use where the chord is usually less than ten inches, but blow up the chord to 27 inches, as we did for the Blackbird XC we just finished, and you begin to see some minor but obvious variations. This is particularly true given the limited number of coordinates we've been using. In addition to smoothing the contour, another goal was to increase the number of coordinates for MacFoil to use during the plotting process.

We took our original BW 05 02 09 coordinates and plotted a 100 inch chord on our Sony 21 inch flat screen display using MacFoil 1.5. We looked at the "jaggies" on the screen and made adjustments to a couple of the points so the step increments appeared better proportioned.

Once everything looked good on the screen, we printed the 100 inch section on paper — eighteen sheets of legal size bond. Using ships curves and an oblique viewing angle down the length of the chord, we refined the existing points and took measurements using a decimal ruler. We also decided where additional points were needed and wrote down rough ordinates for each.

From there we began adding points between the previously established points within the coordinate table, adjusting the Y ordinates until the airfoil segment looked good on the large monitor.

We then used MacFoil to increase the camber by a factor of ten and the airfoil thickness by a factor of five. This accentuated very small differences so that any irregularities could be easily seen. Smoothing this contour consisted of fine tuning the ordinates of just a few of the added points.

The next step was to remove the camber entirely and make sure the thickness distribution looked smooth. A bit more tweaking was found to be necessary. By alternately increasing and decreasing the camber and thickness, we eventually had a shape which looked smooth across both the upper and lower surfaces. Camber percentages ranged from zero to 50, thickness percentages from zero to 100, and lengths up to 200 inches.

Overlaying the new profile over the old showed a few very small differences, but nothing of great significance. In fact the variations between the original and modified sections at ten inch chord length are probably smaller than variations in contour when using an X-Acto blade and a metal template. The added points provide a more defined surface.

Once completely satisfied with the modifications, we took the EH 1/9 airfoil which we know to be smooth and changed its thickness and camber to match that of the BW 05 02 09, plotted it at 200 inch chord on the monitor, and then overlaid the BW 05 02 09. With the smooth contour of the modified EH 1/9 as the background, the red BW 05 02 09 profile looked very good indeed.

The differences between the two sections, EH 1/9 and BW 05 02 09, when adjusted for the same percent thickness and camber, are noteworthy: The BW 05 02 09 has a sharper leading edge back to the area of the high point at 30% chord. This applies to both the upper and lower surfaces. The maximum thickness point of the BW 05 02 09 is about two percent further aft than that of the EH 1/9. The upper surfaces aft of 60% chord match fairly well. The trailing edge of the BW 05 02 09 is thicker. This is especially desirous if you're constructing the trailing edge with wood sheeting. Because of the greater camber line reflex, the lower surface is much deeper.

The coordinate table for the enhanced BW 05 02 09 is included here. As stated previously, this section is extremely close to that used on several of our own aircraft with excellent results. This coordinate table is also available as a downloadable file at our web site: <http://www.b2streamlines.com/BW050209.txt>.

To assure a smooth surface contour, a fellow member of the nurflugel e-mail list, Andre L. Martins, ran our expanded coordinate table through XFoil. The XFoil smoothing process uses inverse design; that is, it smooths the pressure distribution and then derives a "new," practically identical airfoil, using the smoothed pressure distribution. As a bonus, the number of coordinates was increased to 200.

Full geometry similarity was not transferred to the smoothed airfoil. The smoothed section ended up with a slightly greater thickness (from 9.15% to 9.34%) and slightly less camber (from 2.14% to 1.93%). The main contour differences between the two sections are a larger leading edge radius and a significantly deeper lower surface beginning at the leading edge but tapering in magnitude to the trailing edge. The effective aerodynamic differences appear to be negligible. The zero lift angle and pitching moment depend on the Reynolds number, but for a tentative value of Re = 0.3 million (300K), the smoothed section zero-lift angle is -0.33 degrees and the pitching moment is 0.014. This compares favorably with our numbers for the original Foil 1.2 derived section zero lift angle of -0.15 degrees and a pitching moment of 0.018.

Coordinates for the smoothed version are available for download at <http://www.b2streamlines.com/BW050209sm.txt>. Additionally, a five page PDF document showing the before and after pressure distributions can be downloaded from <http://www.b2streamlines.com/BW050209.pdf>.

Our thanks to Andre for the XFoil smoothing. Anyone using either our enhanced version or the XFoil smoothed version of the BW 05 02 09 is encouraged to share their experiences with other *RCSD* readers.

Suggestions for future columns may always be sent to us at either P.O. Box 975, Olalla WA 98359-0975 or <bsquared@b2streamlines.com>.

References:

Drela, Mark. XFoil. <http://raphael.mit.edu/xfoil/> (There are several versions of XFoil available for various Windows systems. According to some members of the XFoil e-mail list, it's possible to run XFoil on an OS X Macintosh. We're trying to track down a version which will work with OS 9.2 and earlier.)

Johnson, Dave. MacFoil 1.5. <http://dogrocket.home.mindspring.com/macfoil.html> (Dave says MacFoil 1.5 will run on any Mac using OS 8.6 and greater, but it works just fine on our G3 Wallstreet PowerBook with OS 8.1.)

Payne, Gregory. Foil 1.2. (Gregory Payne's personal web page with a link to Foil 1.2 has been down for some time. We do, however, maintain Foil 1.2 as a downloadable file on our web site. <http://www.b2streamlines.com/Foil12.sit.hqx>)

<u>BW 05 02 09</u>

1.00000 0.00000	0.00000 0.00000
0.97500 0.00207	0.00010 -0.00050
0.95000 0.00410	0.00040 -0.00117
0.92500 0.00623	0.00100 -0.00175
0.90000 0.00835	0.00200 -0.00265
0.87500 0.01072	0.00375 -0.00375
0.85000 0.01310	0.00750 -0.00550
0.82500 0.01570	0.01250 -0.00722
0.80000 0.01833	0.01875 -0.00883
0.77500 0.02104	0.02500 -0.01025
0.75000 0.02375	0.03750 -0.01262
0.72500 0.02661	0.05000 -0.01445
0.70000 0.02948	0.07500 -0.01716
0.67500 0.03247	0.10000 -0.01931
0.65000 0.03547	0.12500 -0.02081
0.62500 0.03852	0.15000 -0.02186
0.60000 0.04157	0.17500 -0.02269
0.57500 0.04453	0.20000 -0.02337
0.55000 0.04749	0.22500 -0.02402
0.52500 0.05043	0.25000 -0.02467
0.50000 0.05337	0.27500 -0.02513
0.47500 0.05603	0.30000 -0.02549
0.45000 0.05853	0.32500 -0.02579
0.42500 0.06067	0.35000 -0.02611
0.40000 0.06236	0.37500 -0.02642
0.37500 0.06372	0.40000 -0.02665
0.35000 0.06475	0.42500 -0.02691
0.32500 0.06565	0.45000 -0.02706
0.30000 0.06605	0.47500 -0.02721
0.27500 0.06585	0.50000 -0.02734
0.25000 0.06490	0.52500 -0.02733
0.22500 0.06325	0.55000 -0.02731
0.20000 0.06135	0.57500 -0.02721
0.17500 0.05848	0.60000 -0.02711
0.15000 0.05521	0.62500 -0.02685
0.12500 0.05125	0.65000 -0.02660
0.10000 0.04605	0.67500 -0.02609
0.07500 0.03955	0.70000 -0.02556
0.05000 0.03173	0.72500 -0.02471
0.03750 0.02692	0.75000 -0.02385
0.02500 0.02125	0.77500 -0.02281
0.01875 0.01798	0.80000 -0.02174
0.01250 0.01415	0.82500 -0.02041
0.00750 0.01043	0.85000 -0.01875
0.00375 0.00685	0.87500 -0.01662
0.00200 0.00455	0.90000 -0.01400
0.00100 0.00285	0.92500 -0.01100
0.00040 0.00183	0.95000 -0.00777
0.00010 0.00050	0.97500 -0.00405
0.00000 0.00000	1.00000 0.00000

thickness = 9.15%, camber = 2.04%,
C_m = 0.018, zero lift angle = -0.15 degrees