Yet Another Rudder Project

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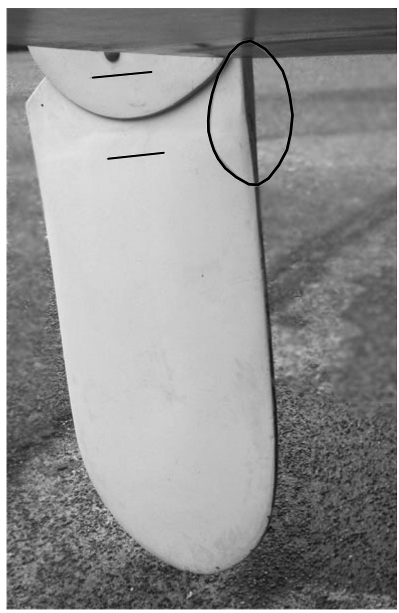
Independent

My 1963 DS1 still has the original stock rudder with its rather primitive foil shape. The foil is essentially flat with a ramp at the leading and trailing edges. Over the decades, the rudder accumulated its share of dings, not all of which were repaired. Worse, the rudder blade developed a crack near the trailing edge and is weeping rust. Normally, I would have been tempted to figure out some cheap fix, but when somebody pointed out that the deficiencies of the stock rudder go way beyond an inefficient foil shape, I accepted the challenge to build a new rudder.

There are several issues with the design of the stock rudder that make a replacement worthwhile. The first problem is circled in the photograph. Right where the water flow hits the rudder below the keel, there are several square inches of a flat surface acting like a brake.



The second problem is in the area between the two lines in the picture. This part of the immersed area of the rudder blade is actually not really shaped, but gradually transitions from a flat slab. By class rules, the pivot bolt is 1" above a line that continues the keel beyond the transom. If the boat is balanced, the immersed area would start 1" below that bolt, as indicated by the upper of the two lines.

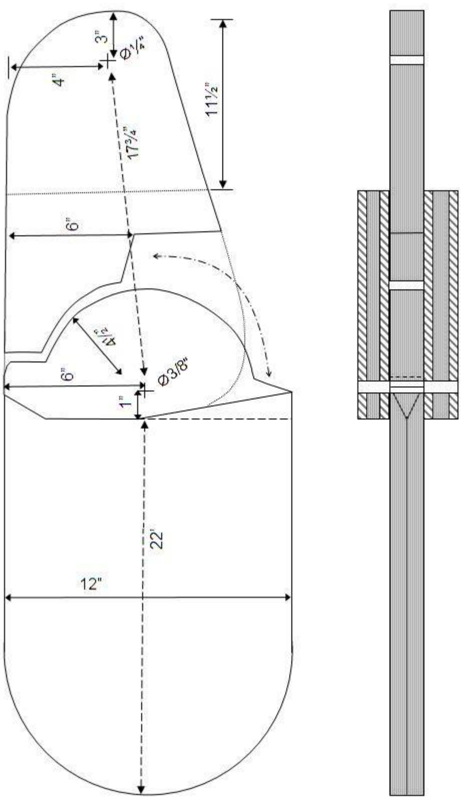
The third problem is that the two "cheeks" which form part of the rudder joint extend unnecessarily far down into the immersed flow, providing an additional source of turbulence and drag.

The fourth problem is weight. At slightly over 16 lbs the stock rudder is quite heavy and any unnecessary weight off the transom is not a good thing.

It should be possible to home build a rudder that avoids these four problems and provides a better foil shape in the bargain.

There is an old Day Sailer Quarterly article by Jim Fisher that gives dimensions and a design for a rudder using an aluminum rudder head that fixes these issues. From my vantage point, the biggest downside of that particular design is the use of aluminum. To me, the use of an aluminum rudder head does not seem to fit particularly well with the looks of an early DS1 with its mahogany trim. I also do not have any tools for working metal, or much experience in that direction. Further, his rudder head design is for a fixed tiller (mine tilts up) and for a different placement of gudgeons.

Therefore, I decided to adapt this design to my purposes and went back to a rudder head more like the one on the stock rudder. I would construct both the rudder and the main part of the rudder head from the same slab of material, and add two separate pieces for the "cheeks" of the rudder joint. As material I decided to use 2 sheets of .5" plywood, glued back to back, which would give me 1" at maximum thickness. After shaping it, I planned to epoxy seal the wood and cover it with a thin layer of glass cloth for protection.



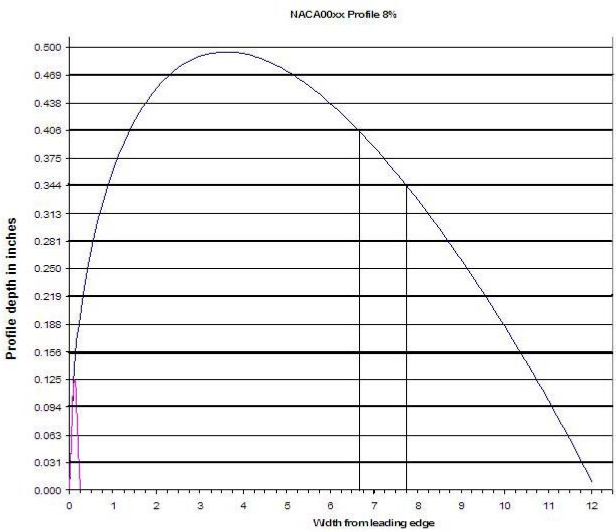
The left half of the drawing shows a side view of the rudder with the leading edge at the left. The rudder head is on the top and the rudder blade on the bottom, both to be cut from the same slab. The right half shows the edge-on view of the rudder, as seen from the trailing edge. Note that the drawing is not fully to scale, but the indicated dimensions should be within the limits for a class legal rudder. The bottom 22" of the rudder blade would be shaped, up to the solid line. The top part of the rudder blade forms part of the joint and must remain flat.

The dimensions and placement of the “cheeks” are indicated with dotted lines. The cheeks themselves are constructed from .25” plywood, with a layer of glass on the inside and a layer of glass mat and a layer of glass cloth (6.0 oz) on the outside, for strength.

The rudder head is designed for a tiller that tilts up. So that the tiller can be used to steer when in its raised position, the head, as on the stock rudder, extends a few inches above the tiller bolt.

The earlier DSQ article did not provide a very accurate drawing of the foil shape. I located a formula with which one can plot the curve for the NACA00xx family of foil shapes. The last two digits correspond to the maximum thickness of the foil in percent of the chord length.

The maximum width of a DS rudder is 12” under class rules, therefore with an 1” slab, something like an 8% foil can be realized easily. This may not be the ultimate optimized foil shape, but given that my goal was to improve on the stock rudder, I decided to proceed.

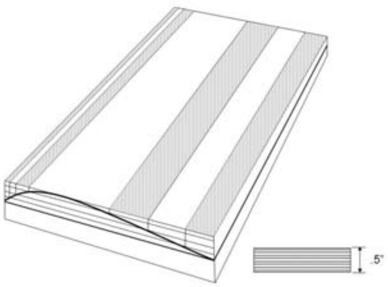


The plot shows the calculated foil shape using exaggerated elevation to make it easier to read values from the plot. The dimensions are in inches.

To shape the foil, I used the layers of the plywood as depth gauges. That is, I marked the expected pattern of dark and light bands that I would get from sanding the plywood into the foil shape. I used a high-grade birch plywood with 9 layers in each .5” sheet of plywood. Seven of these layers are full width, and the 8th is split in half to form the top and bottom veneer.

The small inset in the picture shows these layers. The main part gives a schematic view of how to use the alternating plies in the plywood in helping to shape the foil.

When you sand at an angle through plywood, the result is a banding pattern of alternating lighter and darker stripes. By measuring where the plies intersect the foil curve, you can project the location and width of these stripes.



Marking the stripes on the surface is futile, since these markings will be sanded off. But by marking them on some wood on either side, you can use a straight edge for a quick check whether you have sanded deep enough. I kept the rudder head attached as I was shaping the foil. That gave me a nice flat area to clamp my work piece and to mark these locations.

For rough shaping I used a power plane and a belt sander, starting at 40 grit. Even though I removed a large amount of wood, that was one of the faster steps in constructing this rudder. In my search for foil shapes, I had not come across any good discussions on how to taper the foil towards the tip, so I essentially eyeballed this part. Having the contour lines in the plywood allowed me to compare the way their pattern curved toward the tip, making sure that the taper is symmetric on both sides.

After getting the basic shape right, at least to the point where there weren't any bumps or high spots, I sealed the wood with laminating epoxy and added a light layer of fiberglass cloth (3.7oz). I then covered the rudder blade with epoxy filler in preparation for fine shaping.

It is important to cover both the blade and the rudder head with the same fiberglass to make sure that the gap between the cheeks of the joint is wide enough to accept the semicircular top of the rudder blade. I used a jigsaw to cut the outline of the rudder head and to separate the rudder head from the rudder blade, but left them connected by a few small tabs of wood. That way, I could laminate both in the same operation, and would not need to make long cuts through the fiberglass later.

After cutting apart blade and head, I prepared the cheek pieces by glassing their inside, before gluing the cheeks to the rudder head with epoxy. I then faired their upper ends into a slope (not shown in the drawing) before finally applying the glass mat and cloth on their outside.

At this stage, after letting the epoxy cure for a few days and sanding smooth the area of the rudder joint, I drilled and reinforced the holes for the rudder and tiller bolts. The rudder bolt is a 3/8" carriage bolt. I epoxied a nylon bushing in one cheek, and filed the hole in the other cheek to a square, which I reinforced with epoxy. The tiller bolt also got a nylon bushing.

A test assembly showed the need to sand down the top of the rudder so it would clear the rudder head and allow a full 90° swing.

Next, I suspended the rudder at the top of the head and the tip of the blade and applied 250 lbs to the middle to do a strength test. At that load, there was a bit of give, but no cracking and from with a bit of research I convinced myself that this test simulated realistic extreme loads on the rudder.

The photo shows how the shape and design of the new rudder avoid the basic problem areas for the stock rudder. Note, despite the optical illusion, the rudder blade does not have an asymmetric tip.

For final shaping of the rudder foil I used two different methods, both done by shining a light from one side. For the first, I placed ruler lengthwise, parallel to the stripes, and observed whether there were any low spots (light shining under the straightedge) or corresponding high spots. Sanding with a very long and hard sanding board along the lengthwise direction helped fair the foil.

For the second method, I used a printout of the foil shape 1:1 onto a piece of cereal box. I cut along the curve with a sharp knife and then soaked the edge of the cardboard in epoxy. That allowed me to use sandpaper to get a fair curve on this cardboard template. I then used this template in the direction across the foil, again with use of the light, to find out high or low spots.

The high spots I sanded off as before, the low spots I filled with the epoxy filler. The filler took 4 hours to cure, and I repeated that process several times over the next few days.

For finishing, I could have followed the prescription from Mike Gillum's article on boat finishes in the fall 2010 DSQ. Instead, I decided to use a one-component polyurethane topside paint, because it's less sensitive to curing temperatures and easier to apply. Whether I will regret this choice in the long run remains to be seen – unlike a boat bottom, repainting a rudder is far less of an operation.

The whole process took about three weeks, much of it spent on waiting for paint, epoxy or filler to cure. I estimate that I spent something under $200 on supplies and materials. I could have saved $30 by reusing the stainless steel hardware from the existing rudder, and I have enough paint , epoxy and filler left over to build another rudder. The new rudder is about 5 lbs lighter than the original. The final photo shows the new and old rudder in comparison.