Replacing motorboat rudder

The (non-original) rudder that was under our Barkas 1100 at the time of purchase seemed clearly designed for maximum effect during maneuvering. Putting the propeller forward briefly, with the rudder on board, causes the the stern to swing immediately. The balance part (surface before the rudder shaft) is very large so that the rudder can catch a wide flow of water from the propeller.
The horizontal plates at the top and bottom guide the water along the rudder's profile.

However, this rudder has considerable disadvantages when sailing: The rudder is very sensitive and it requires constant attention to keep the ship on the desired course. In narrow waters with current, or in places where the water swirls, such as near bridges, the ship sometimes reacts unreliable to course corrections. In addition, there are situations, at certain rudder angles and speeds, where the rudder starts to flap. This flapping usually stops when the propeller is put in neutral.
Also during steering with the (emergency) tiller, with the bypass crane of the hydraulic cylinder open, flapping occurs and the tiller shocks.

New rudder design - November 2021
When steering by hand hardly any force was required, even at greater speeds. The pressure point, the starting point of the lateral force on the rudder, appeared to be very close to the rudder shaft. This explains the possibility of flapping. The balance part (32.5%) was clearly too large.
It was therefore decided to make a new rudder with a smaller balance part.
In addition to the course-stable steering while underway, it is also important, for example in evasive situations, to be able to steer well at low speed, without extra propulsion. By making the rudder higher, the unobstructed flow of water above the propeller can be better used for this.
In addition, I wanted to pursue a smaller resistance.
Publication MT521 of TU Delft, was one of my guiding principles. Chapter 12 describes various studies on rudder profiles. My choice fell on a symmetrical NACA0018 airfoil. The number indicates the greatest thickness as a percentage of the cord - In our case 18% of 550 = 99 mm. The dimensions of NACA0018 profiles and further explanation are given in a separate pdf on the download page.

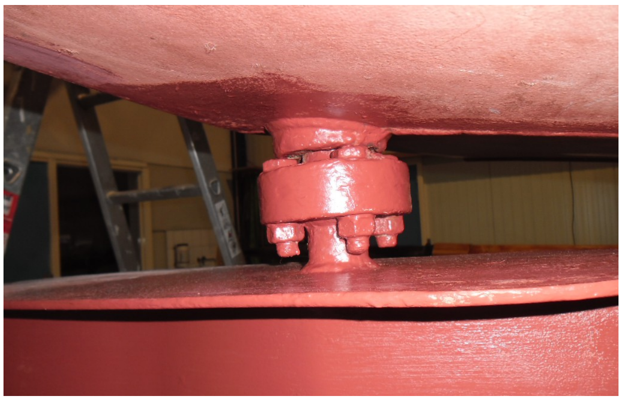
The flapping
With a symmetrical NACA profile, the theoretical pressure point is about 25% of the cord from the front. So with a more moderate (and more common) balance part of 20%, the pressure point clearly remains behind the rudder shaft. As a result, although more force is needed to steer, that force will no longer (unwanted) change direction (in other words, flapping will be avoided)
Due to the smaller balance part of the new rudder (from 32.5% to 20%), the leading edge of the rudder will be at 19 cm from the propeller and therefore also in slightly more homogeneous water.

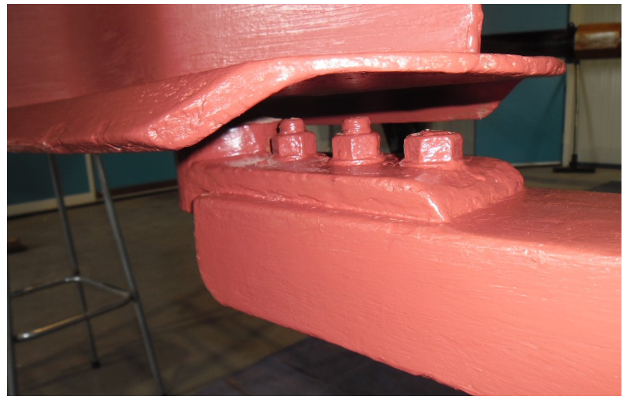
Rudder height and surface

By mounting the flange of the rudder shaft directly on the rudder, the rudder at the top can become slightly higher. At the bottom, the pivot spot for the new rudder is mounted from the bottom into the U-shaped heel in stead of on top. In total, this allows the new rudder to be 8 cm higher. The surface area of the new rudder (H 680 x L 535 mm) will be 8% larger than the current rudder and therefore almost the same as with the original design.

The new rudder protrudes 3 cm further back measured from the rudder shaft.

The place of the rudder shaft (through the hull) remains the same. The photos show the old situation:

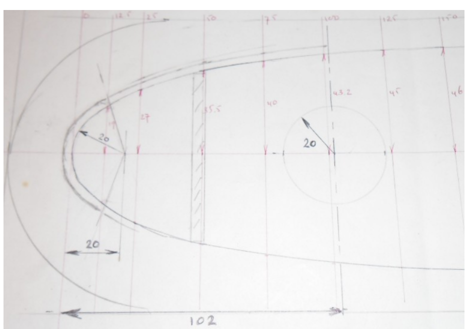




To limit the flow of water over the top and bottom, I use protruding plates there, just like with the old rudder. This also makes cutting out the profile shape superfluous. In addition it provides a step towards the swimming ladder on the stern, which is less sharp and more pleasant to use with bare feet.

The construction

To get the desired profile shape, the side plates are bent over vertical strips. The strips are welded to the top and bottom plate. The front is formed by a pipe segment.



The segment of the pipe used is somewhat larger than in the theoretical profile shape. This has been done to maintain sufficient stiffness and to avoid very sharp bending of the side plates at their leading edge, with a greater chance of asymmetry.

After sawing and grinding the pipe and after weighing the 2 parts, I arrived at 144º.

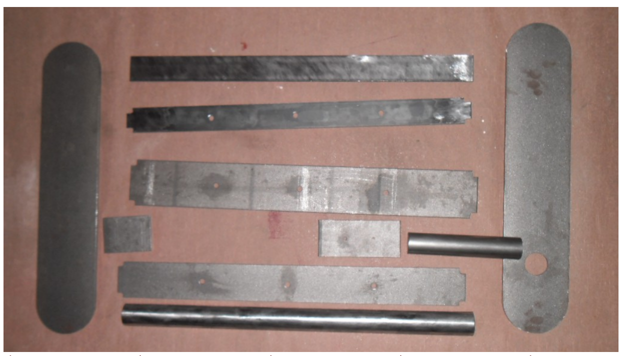
(360 x 1090 g/ 2709 g) For sawing I used a saber saw.

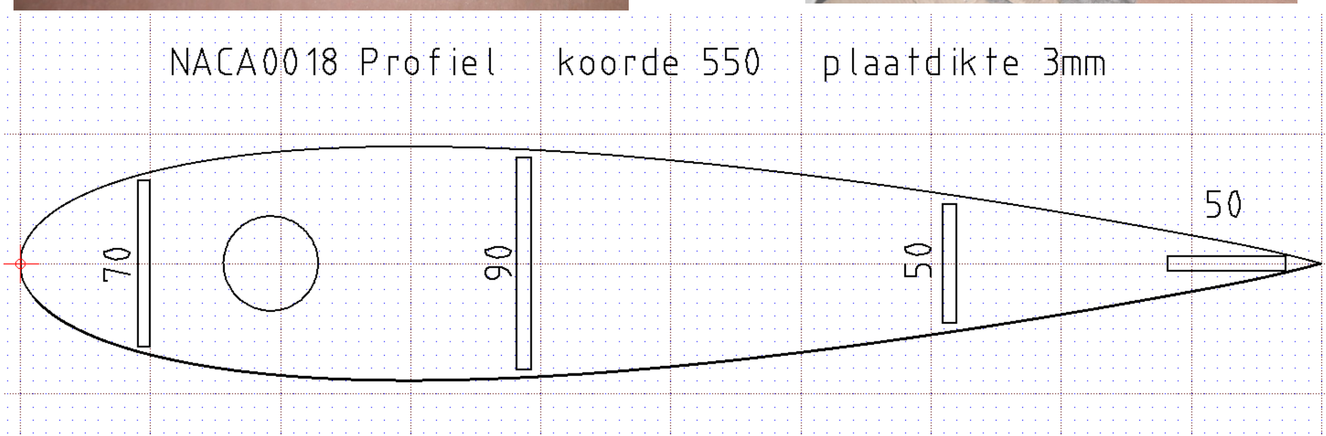
Important if you are going to apply the content of this report

This rudder fully meets my expectations but it does not automatically have to be the best solution for you. It is advisable to orient yourself as broadly as possible and, depending on your own situation, goal and experience, to take the appropriate decisions and associated safety measures.

The author cannot take responsibility for the result of work, accidents, malfunctions, etc. as a result of this article.

Construction parts and weight	**gram**
Edge aft strip 668 mm flat 50.6	1603
Aft strip 668 mm flat 50.6	1563
Middle strip 668 mm flat 90.6	2662
Forward strip 668 mm flat 70.5	1793
Shaft 200 mm diameter 40 mm	1985
Shaft support 155 mm flat 70.5	428
Plates 2 x 668 x 515 3mm plate	16200
Pipe segment 668 mm diameter 48.40 144º	1090
Top plate 580 mm flat 120.6 (rounded)	3000
Bottom plate 580 mm flat 120.6 (rounded with hole)	2933
Double plate 95 mm flat 70.5	264
Total	33521





Marks on parts/ scratch:
Center lines on all flat parts.
Lines on top and bottom plate from forward at:

20 mm	front pipe segment
70 en 75 mm	borders front strip (70.5)
126 mm	center line ax
230 en 236 mm	borders middle strip (90.6)
410 en 416 mm	borders aft strip (50.6)
505 en 555 mm	borders edge strip (50.6)

The NACA profile ends at the end of her cord (550) at a thickness of 0. I don't want to make the rudder that sharp. I therefore let it end at 535 mm with a strip of 6 mm thick. The plates end at approximately 525 mm and are welded against the strip. The extreme edge is therefore not formed by a weld but by a straight strip. The straight truncation of a symmetrical NACA profile does not cause a measurable increase in resistance up to a width of 2% of the cord.

The position of the trusses was verified on a 1:1 drawing of the NACA0018 profile (on a workbench) using a plastic sailing baton. The bar was clamped and held at the location of the future attachment points (strips) and I checked whether the curved baton followed the shape of the profile correctly.

Work before assembling the rudder

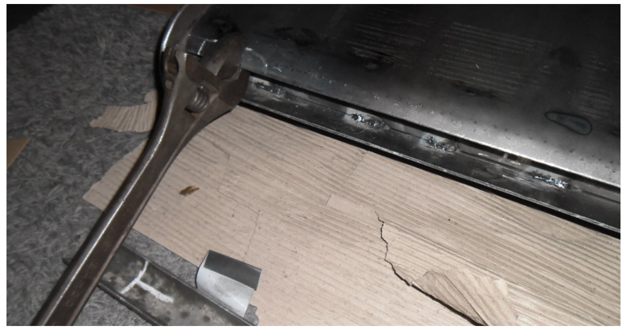
I started with drilling small holes in the double plate of the flange connection. The diagonal bolt distance of a standard flange, k = 75, has been maintained. The bolt holes are, as with the existing rudder, drilled longitudinally so that the wedge in the rudder king, and thus the tiller of the hydraulic cylinder, can be mounted in the same position.
Drilled at 2.5 and 4 mm
The double plate welded and pierced exactly at the correct place at the bottom of the top plate: 4-6-8-10.5. The holes then provided with thread M12.

The bottom plate has a hole for the shaft.
The top and bottom plate rounded.
The trusses are equipped with holes and gates so that paint can pass through internally.
Where necessary, clean (oil from drilling and tapping) so that the paint adheres better.

The lower part of the rudder shaft welded to the short support strip.
The shaft at the bottom only needs to hold the rudder in place in the pivot spot and does not need to transfer any torsion. It is 20 cm long to facilitate straight alignment on the rudder. Sticking completely through the entire rudder would be of no use: The steering torque is already transferred to the top plate with the flange connection and distributed over the rudder via the outside of the rudder (extreme fibers). Proper alignment of the rudder shaft is a matter of drilling the holes for the flange and shaft in exactly the right place.

Assembling the rudder

It is important to put the rudder together in a pure plane to get a straight end result. During assembling I used a few straight beams to support and clamp the parts.

After each plate was attached, its leading edge was, very gradually, curved with a Bahco to reach the pipe segment. With the rudder flat on the ground the edge was bent until the Bahco touches the ground. Then, with the rudder on boards, bent further with more steel in the mouth of the Bahco. By always using the ground as the final position, the degree of bending can be carried out, the same over the entire height,

The weld of the pipe segment with the plates, I dropped something within the matching line of the desired NACA profile. To get a smooth stroked shape, my preference is to use some epoxy putty, instead of grinding away (possibly too) much welding material. The leading edge of the plates is therefore bent a fraction too far inwards.

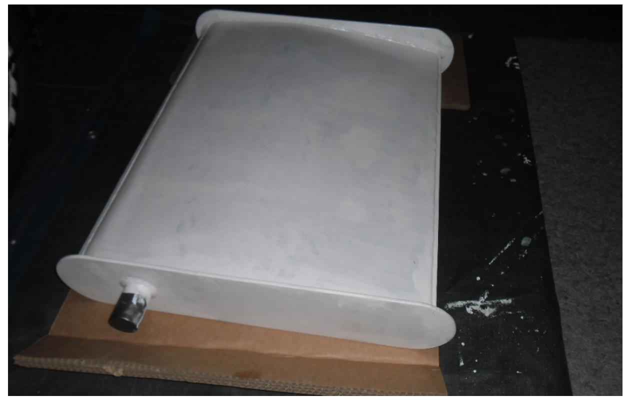
 

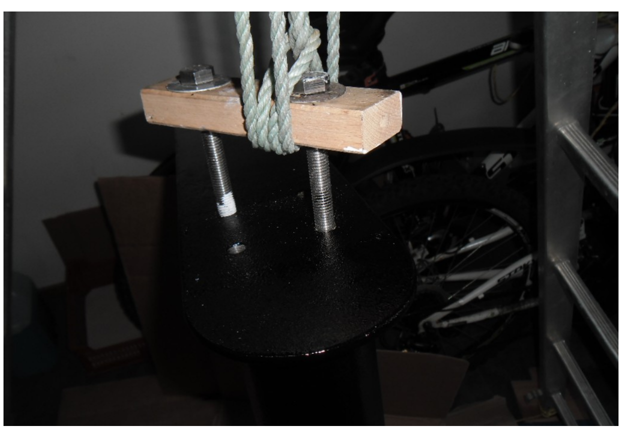
With the second plate (port side) welds through slots are made to secure the plate to the middle and rear truss. The front truss can still be welded from the front as long as the pipe segment has not yet been placed.

After assembling and adhering, I had the rudder welded by an experienced welder with more modern equipment. Then had it shot blasted mechanically. (Closed the bolt holes before blasting and protected the rudder shaft with a plastic pipe)

After blasting, the welds were made a little flatter at some points so that they do not protrude above the putty / paint layer.
Paint system: Degreaser, Epoxy primer, Epoxy putty, Epoxy paint and Anti-fouling.





To facilitate the curing of the epoxy paint, some of the painting is done indoors. While painting, the door was kept open because with this type of paint good ventilation is really a serious point!
In case water ever penetrates into the rudder, for example at the flange connection, I poured paint into the rudder through the bolt holes. Then I turned the rudder in all directions at a leisurely pace, so that the seams, which are not welded on the inside, are filled with paint. (I had a jar of two-component polyurethane paint with a color I wouldn't use anymore) After this "rinsing" of the rudder with paint, I

let the rudder leak out through the bolt holes. This is to prevent the holes at the bottom of the rudder from closing with paint. This way the rudder can be drained (if ever needed) in the mounted situation by drilling a hole in the bottom.

Weight

The weight of the new rudder (painted): 36.5 kg (old rudder 51 kg)
With the rudder shaft mounted: + 6.5 kg
The volume of the new rudder is about 24.5 liters.
In the water, the vertical force on the pivot spot will therefore be about 20 kg.

Assembly April 2022

Old and new

Max to Port *35.5°*

The result

While under way , the ship now steers more calmly and the rudder no longer flaps. Hand-steering requires a light force on the 80 cm long emergency tiller. Steering while maneuvering is at least as effective and the effect of reversing has been improved. The ship remains, slowly floating in calm conditions, well steerable. On the photos above it is easy to see that the rudder, even with a stationary propeller, still receives enough flow to be effective. Improved resistance appears to be somewhat visible at low speeds. Between 1000 and 1800 RPM the ship now runs about 0.2 km/h faster. At 1200 rpm, the biggest difference was seen: from 8 km/h to 8.4 km/h.

Contact with the author

Should you decide to construct a similar rudder, I am very interested in its dimensions in combination with the data of the ship. In addition, in the result and some photos. Thank you.

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