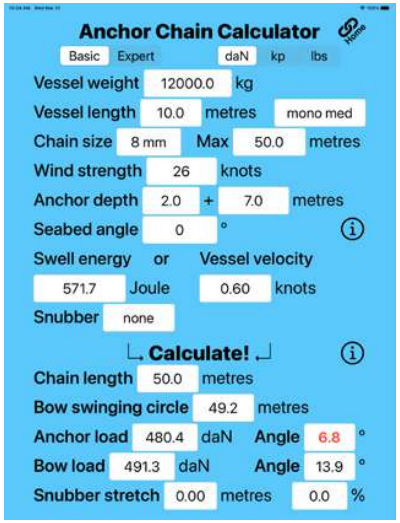
Simplifying the physics of anchoring

By Phil Ross

Mathias Wagner has lived for almost two years on his yacht, mostly at anchor. In that time, he has seen the odd boat sink due to mistakes made from choices in anchor chain length and type of anchor. Many more has he seen dragging past.



The AnchorChainCalculator interface

Noting the danger, not only for the yacht owners but also for vessels around them, he decided to put his training to work. Mathias is a physicist and has been sailing since his late forties, first with beach catamarans then on a Dragonfly trimaran and now, since 2019, he and his partner Birte live onboard their Neel 51 trimaran.

Noting that the German sailing association, plus many other official yachting groups and individuals worldwide, recommend a 3:1 anchor chain rode length compared to water depth, Mathias reasoned this is inadequate and requires a better understanding of all the variables.

His research has led him to design a simple app for any yacht owner to use that gives a more definitive answer on rode length, anchor chain size and snubber/bridle choice.

His analysis includes the effects of swell; why snubbers and bridles are useful in shallow water; whether you should pick an anchor chain that is long and thin or short and thick. Also considering that choice may also depend on the anchorage site.

Wagner has a PhD in physics, plus studied mathematics, so this kind of analysis was like a dream come true.

While Wagner's analysis is steeped in mathematical detail, let us look for a simpler explanation. The graph on page 59 displays the elasticity of an anchor chain according to wind strength and, although it may look complicated, the explanation is simple and important for the entire story.

On the left it is calm, on the right it is stormy. The horizontal axis is scope: i.e. the ratio of chain length to water depth; only chain no longer in contact with the seabed is included in the calculation. Anything still lying on the seabed does not count.

The vertical axis is elasticity divided by the maximum value at the peak, which is, obviously, at 100 per cent. This graph is remarkable as it is universal: just a single curve that holds for all size chains! It turns out that the absolute value of the elasticity is proportional to the water depth at the position of the anchor.

It can be clearly seen the graph has a peak where the chain works best.

A simple example may easily explain: You anchor in a depth of five metres, measured from the bow roller. The wind is light, so you pay out 100 metres of chain, but they are not being used yet because there is almost no wind. So, currently, you are now on the far left of the diagram. The elasticity of the chain is poor, but that does not matter because there is hardly any wind.

Now the wind starts to increase, as you slowly move to the right in the diagram note how quickly the curve rises. When at a scope of 1.4, where chain lifted off the seabed will total 7m (1.4 x 5m of depth), now we are at the maximum elasticity of the chain (100%).

Of course, this is still not a lot of wind: just 7m of chain is needed so that it still pulls horizontally at the anchor in a depth of 5 metres. Now, when it blows even more, we are moving further to the right, away from the maximum where the elasticity of the chain drops steadily.

Note at the oft-recommended scope of 5:1 your chain registers around 40% elasticity.

When your 100m of chain is completely off the seabed, you have reached a scope of 20:5, about 10% elasticity, at the far right edge of the graph. From here, no matter what happens, if you pay out more and more chain it becomes less and less elastic. In other words, it is less and less able to absorb strong gusts or swells.

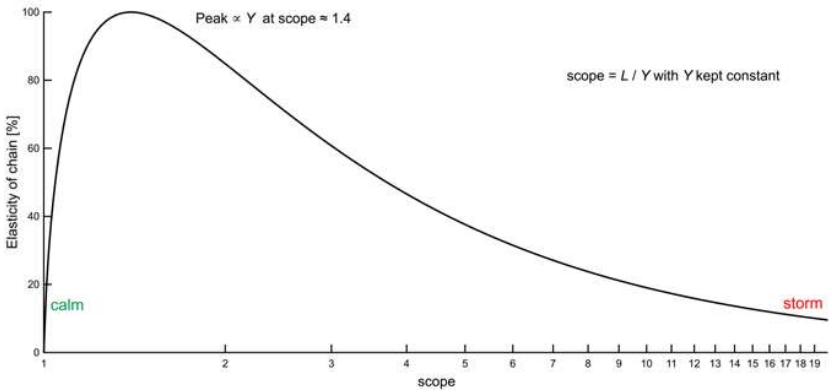
Sure, it can cope with large static forces of a steady wind provided the anchor still holds and the chain does not break; but gusts and swell, no way. That energy must be absorbed elsewhere and, hopefully, not by pulling out the cleats at the bow.

Consequently, you need a rather good snubber or bridle to absorb these peak loads. Because of the general bent shape of a catenary, this effect is much more pronounced in shallow water than in deep water.

For your chain to work well one needs to be close to the peak, which usually means somewhere near the right-hand side of the peak. The deeper one anchors, because of catenary, the smaller the effective scope will be that is required to keep the chain pulling horizontally at the anchor. So, consequently, this diagram suggests anchoring in deeper water, if one has enough chain and if the swell there is not worse than in a more shallow, sheltered anchorage.

Wagner points out six areas where his 'Anchor chain length calculator' app provides a better answer to the perennial question. Available in either Android or on the Apple store.

Using the fixed scope often recommended, such as three to five times the water depth as length of chain, is inadequate, claims Mathias. It is not enough in shallow water and it may be too much in



Graph 1: Scope & Elasticity of Chain

12000 kg weight, 8mm chai, 10m mono hull, 26kn wind, 0.6kn vessel velocity at anchor	5m ⚓ depth	9m ⚓ depth
No snubber	50m chain ⚓: 1322.1 daN, 4.4° 0m stretch	50m chain ⚓: 480.4 daN, 6.8° 0m stretch
Excellent snubber	37.9m chain ⚓: 171.3 daN, 0° 1.55m stretch	48.9m chain ⚓: 156.1 daN, 0° 1.46m stretch

deep water; plus, it does not depend on the wind strength at all, which is odd. So, his app takes a more detailed account of the variables, which are easily entered by the yacht skipper.

The app is much more than a simple catenary calculator. A simple catenary calculator cannot cope with dynamics such as gusts and swell. For shallow water and regardless of swell, a simple catenary calculator would happily spit out a certain amount of chain that is needed.

Wagner's app calculates the minimally required anchor chain length, the anchor load, the bow load, the various pulling angles, swinging radius, etc. all as a function of a number of parameters that depend on the vessel's characteristics as well as the weather. You can also limit the maximal length of the chain. It uses the graph as its guide. The app can handle seabeds with slope, it is surprising to see what strong effect that has.

In 'basic mode' the app removes complicated parameters such as windage area of the vessel. Instead, the app asks for vessel length and some basic characteristics: mono, cat, tri, and what basic shape it has. The description of snubbers/bridles is qualitatively done in this mode, but a custom field does exist where you can specify the snubber/bridle as you would do in 'expert mode'.

You can play around with all kinds of scenarios: is my anchor gear still up to it when wind and swell increase to such and such? What if I improve on the bridle? Is my bridle up to it in 60 kn of wind? Or will it be stretched too much and snap?

Let's have a look at one scenario detailed by Wagner using the Anchor Chain Calculator app, see table above. Four different scenarios are in play while, common to all these scenarios, are the following parameters: vessel weight: 12000 kg, 8mm chain, 10m monohull, 26kn of wind, a large swell, leading to a maximal vessel velocity at anchor of 0.6kn.

The chain length is limited to 50 metres, which are fully needed when no snubber is deployed. Without snubber, when anchoring in 5 metres water, the anchor load is excessively large with 1322daN, which the anchor is not likely to be able to bear.

Moving to deeper water, 9 metres, this load has come already down to 480daN, albeit with a slightly increased angle of pull at the anchor shaft. Then, adding a snubber, reduces the anchor load significantly to 171daN and 156daN, respectively, while the chain length required is less.

Clearly, moving to slightly deeper water and using an excellent snubber is making a huge difference to the anchor load. It should be noted that this snubber is more than the short snubber only too often seen. It needs to stretch by 1.55 metres and, since nylon should not stretch by more than 15% or so, this means the snubber/bridle needs to be at least 12 metres long.

Of course, if the swell in the deeper water is much higher, it is not an option to move there. But if the swell is similar at both places, it makes a lot of sense to relocate.

Such scenario play will easily convince you that anchoring in shallow water, with lots of swell but no snubber or bridle, is not a smart idea. It will increase the anchor load multiple times over.

It is better to move to somewhat deeper water, where the same swell has less impact and, better yet, use a very good snubber or bridle on top. When doing so you may not even need to pay out more chain, which might be a surprise to many.

Go to your app store and search for AnchorChainCalculator (all one word).
Also scan the QR code to check out Mathias Wagner's full explainer on the app. ⚓