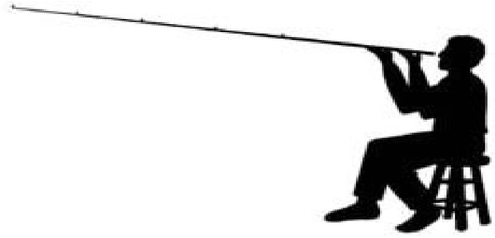
Load Up!

by Dave Hauser

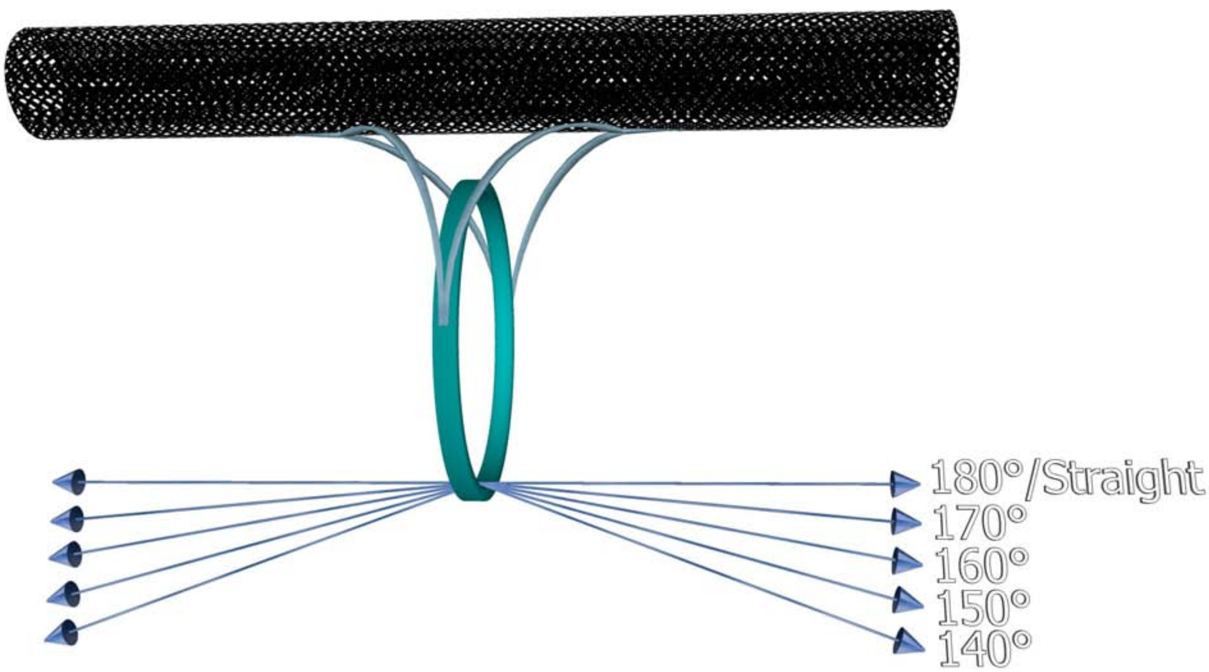


Custom Rod Builders Guild

As simple as a fishing rod may seem be, it is also a piece of engineering. Knowing something about the science behind some of that engineering can help you to build a better fishing rod. One of the more important things to know is how stress is distributed over the blank. A few years back, Cliff Hall and I crossed paths on this topic. I was working on it from a pragmatic aspect of how to actually distribute and manipulate stresses, and Cliff was more interested in the analytic engineering of why loads and stresses were what they were. Now that Cliff has passed on to angling greater waters, where no licenses are required and all the fish are big, it seemed fitting to describe a key piece of our combined research.

The interaction between the blank, the line tension, and the guidetrain can focus or alleviate stresses. Stress distribution is actually the main goal of static testing and tuning, and it does it quite well if an attentive eye is used. Part of how this is done is by trying to closely match the line path to the blank bend, throughout the various bending motions of the blank under load. The angle of the tensioned line at the guides is also an important part of static tuning.

Guide Loading



Consider that line is tensioned by a load, and the line forms an angle at a guide as it passes through the guide. That combination of tensioned line and line angle produces a force on the guide. I once used scales to measure the force, but that was some time ago and certainly open to a fair bit of measurement error. Cliff worked on proving the force could be derived directly through a formula by simply knowing the amount of line tension and the angle formed. He was correct, but unfortunately did not live to see the verification of his idea.

The proof of Cliff's work was eventually validated by Denis Brown. The vectored force at an angle to the input force is proportionate to the Cosine of the angle. Where you have tensioned line which forms an angle at a guide, the formula for the vectored force on the guide is:

Where LT = line tension, and, Theta = the angle formed by the line in degrees
Force = LT * Cosine(Theta/2) * 2

So for example, using five pounds of line tension the following results could be obtained. The 'Multiplier' is the rounded result of Cosine(Theta/2)*2 and is convenient to see the escalation of force as the angle reduces.

LT (lbs)	Theta Angle	Multiplier	Force (lbs)
5	180°	0.00X	0.00
5	170°	0.17X	0.85
5	160°	0.35X	1.75
5	150°	0.52X	2.60
5	140°	0.68X	3.40
…	…	…	…
5	90°	1.41X	7.05
5	75°	1.59X	7.95
5	60°	1.73X	8.65
5	45°	1.85X	9.25
5	30°	1.93X	9.65
5	15°	1.98X	9.90
5	0°	2.00X	10.00

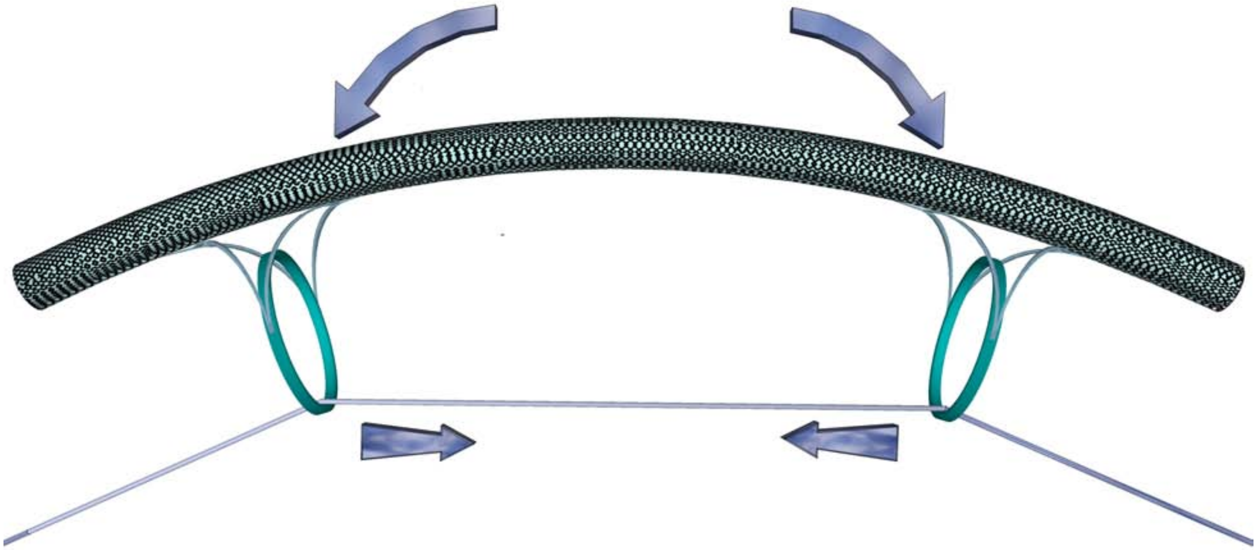
From the results, a few things become apparent. An obvious point is that if there is no line angle formed at the guide by the tensioned line (Theta=180), then there is no force applied to the guide. I call this an 'unloaded' guide, while a guide having force applied to it I call a 'loaded' guide.

Another point that is not that intuitive is that more force can be applied than there is line tension. The generated force can be up to 2X of the load amount used to generate the line tension. So far as individual guide loads, it is unlikely that you will ever be under 150°. Certainly you shouldn't have such a condition! But there is a follow-on application where those higher multipliers become involved.

At its simplest, The force on an individual guide tells you something about how robust that guide and its wraps need to be, and how much frictional pressure the line itself must endure as it runs against the loaded guide. One surprising revelation to some people may be simply looking at the individual line angles generated when bending a conventional rod. Look at those angles and you will find that the stripper is typically NOT the guide with the highest load. Usually the highest load will be on guides further out where the rod bends the most.

Now consider the interaction between multiple guides. The more powerful the force on two adjacent guides, the more stress there is on the blank section between them. And the more distance there is between loaded guides, the more stress there is on the blank section between them. As an analogy, consider how you would break a twig between two hands. The further apart your hands, the easier it is to bend and break the twig. Same with a rod blank, the further apart the loaded guides, the easier it is to bend and break. This is why you risk breakage when you spread loaded guides too far apart.

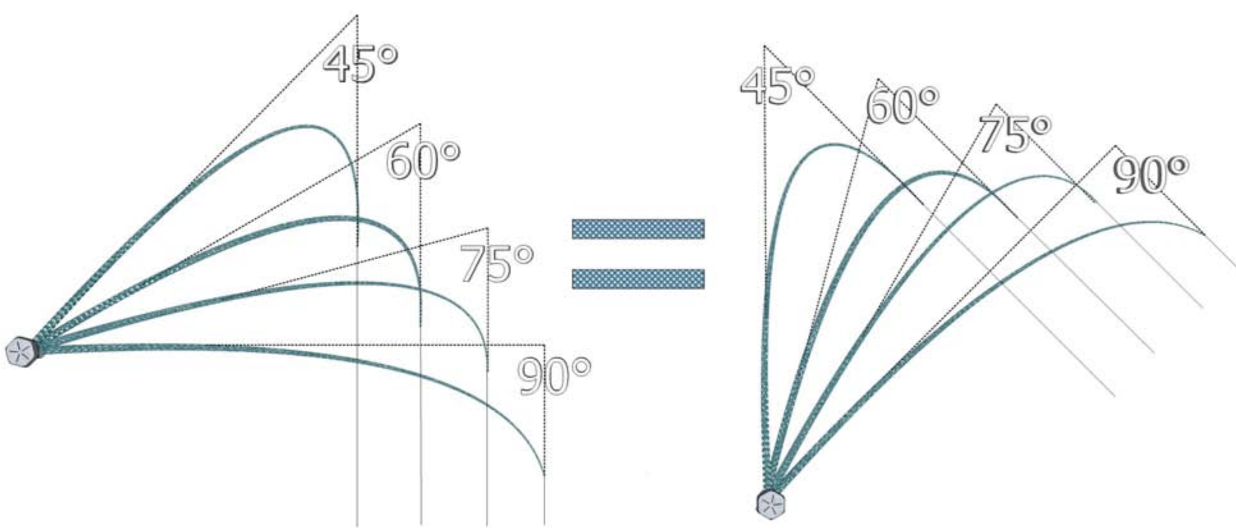
There is another related part of the interaction between loaded guides that I will briefly mention: adjacent loaded guides pull towards one another and therefore bend (stress) the blank between them even more. This is a compounded leverage generated by the force vectors of the guides themselves. The greater the line tension force at each of two adjacent guides, the greater the two guides will pull towards each other and stress the blank between them. It seems very complicated, but again, that leverage effect is ultimately powered by the line tension forces between the guides and the line angle at those guides. Minimize and balance those line angles by guide placement and guide size selection, and you take the teeth out of the compounding effect.



What these few points reveal is the wisdom of observant static testing, where you endeavor to balance the loads amongst the guides, and minimize acute angles by adding guides or rearranging them along the blank. How you perform your static test is also important, because the interaction of the guidetrain and the line tension can change how the blank is stressed. Because of this, the truest way to load a rod for static testing is by loading the guidetrain and not merely tying a weight to the tip.

Angle of Attack

The Cosine function also has a larger application towards fishing rods. Let's say you tie a load to the end of the line, and now you point the rod in exactly the opposite direction of the load. The angle of the rod to the load is approximately 0°. Plug that into the equation and what you come up with is a multiplier of 2X. In other words, the force going into the rod is two times the amount of load. Now point the rod directly at the load. The relevant angle is 180°, which yields a multiplier of 0X, and thus no force is going into bending the rod.
Note: This is conceptual, but the reality is quite a bit more complicated, since blank and linepath are going to be different. If you understand the concept, however, you attain most of the intended message.



Consider all the normal angles you are likely to use a rod. After analyzing pictures found online showing people fighting fish, the most common butt to loaded line angle was around 90°. At 90° the multiplier is 1.41X, which says that the total force being applied to the rod is 1.41X more than the fish is pulling. Note that it does not matter if that 90° is happening because you are holding the rod level and the line is going straight down, or whether the fish is way out there and you are holding the rod tip up. The force generated is defined by the line angle formed between the butt and the loaded line. And finally, consider what happens when you land a fish or get to the apex of pumping the rod. You are not at 90° anymore, and let's say your butt to line angle is 45°. The force being put into the rod increases to 1.85X. This escalation in total load, as the butt to line angle decreases, is largely what powers highstick breaks, coupled with the progressive confinement of that load to a smaller section of the guidetrain, and compounding between the guides in that section of guidetrain.

Wrap-Up

The complexity of the physics operating on a fishing rod can be daunting. The Cosine function merely scratches the surface, but it is one of the primary drivers of the forces involved. Hopefully this discussion will leave you with a basic appreciation for why the line angle at a guide matters, the importance of good static testing in building a rod, and the escalation of forces involved that leads to things like highstick breakage.