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ANCHOR SYSTEM SELECTION

by Don Dodds

INTRODUCTION

You recall in our last episode, that Tom had just explained to sheriff Mike;

- the anchor type must match the bottom conditions,
- the anchors must be set properly to hold properly,
- composite rodes can hold effectively at short scope,

As we join the pair today sheriff Mike is mumbling something about not owning an anchor. As they sit around the campfire Tom starts to explain that now that we have a background in anchor loads and how to use anchors we are in a better position to select a proper anchor system.

ANCHOR SYSTEM SELECTION

The selection process consists of comparing component load and strength values. As we have seen earlier, the traditional approach is to use simplifying assumptions, with extremely high safety factors and hope the safety factors cover the unknowns. We have also seen that this process has led to considerable over design for normal anchor use, yet leaves us with a system that is likely to fail under extreme conditions. Using some of what we have learned in the last two articles, by approaching the problem from a different direction, we can reduce the over kill and provide a safer and user-friendly system.

There are four basic parts to an anchoring system, the boat, the rode, the anchor, and the bottom material. See Figure 1. As in any system, all components must be matched in strength, for the weakest member will fail first. Let us examine each of these components independently to see how it affects the overall system.

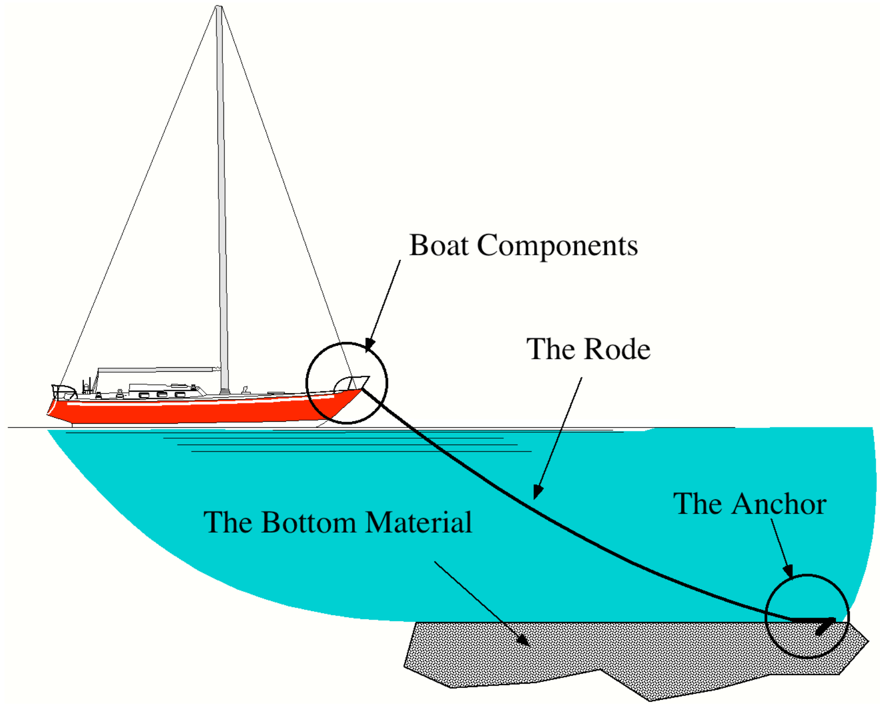

Figure 1 Anchor System Components

Bottom Material

History shows the weakest member to be most often the bottom material. In other words, anchors drag much more often than rodes part. Unlike nylon, steel and fiberglass, we know little about the strength of bottom material and as such, it is most often neglected in the design or selection process. Bottom material strength depends on the material's composition (i.e., sand, silt, clay, gravel, etc.) and density, the shape of the anchor and the direction of the load. The material composition and density varies greatly from anchorage to anchorage and even from place to place within a given anchorage.

In truth, the strength of bottom material can change any given anchor's holding power from a few pounds to thousands.[1] Most experts deal with this variability by classifying bottom material into a couple of broad groups, i.e., *weak* and *good* material and by selecting an anchor so large that it will hold reasonably well in the weak material. Covering this large strength range with only two classifications is a gross understatement. Too bad we can't just buy some good bottom material and cart it around with us.

However, it turns out that this problem can be neatly avoided by using the procedure outlined in the previous article on how to set the anchor properly. This technique provides the user with significant information directly applicable to the strength of the bottom material relative to the anchor de jour. As we have seen earlier, different type anchors react differently to different bottom conditions and, how well an anchor is buried determines to a great extend how well it will hold. Since setting loads are always less than breakout loads, by setting the anchor at maximum throttle, at maximum scope, we have actually ran an in-place test on the anchor's minimum holding power. The boater can now safely assume failure will not occur until conditions increase the load beyond the level reached during setting.

Further, if the resistance factors for the boat have been calculated or measured the boater can predict the expected static loads at which the bottom material will fail. Listening to weather reports before you anchor will reduce the number of times, conditions will increase beyond those expected. If conditions are expected to be greater than the anchor will hold, reset the anchor, change anchors, use two anchors or move the boat to a harbor with better bottom conditions. This method allows the boater to be pro-active and have considerably more control over the outcome.

[1]Dodds, Don, Modern Seamanship, Lyons & Burford, 1995, page 159.

Anchors

The anchor component of the system is where the snake oil starts to ooze. Sort of like painkillers, we find all sorts of claims and testimonials but little hard data. Normally anchors are selected based on one of three different anchor loads, a lunch hook (15 knot wind), working (30 knots wind), and storm anchor (60 knot wind). These names have on occasion been linked to a recurrence period. A few hours for a lunch hook, a few nights for the working anchor, and the storm anchor on occasions when the boat is unattended for long periods. This results in the normally used anchor to be selected on the basis of 30-knot winds.

In reality only one in a hundred times are anchors used in winds of 30 knots or greater. Most overnight anchoring is done in winds less than 15 knots. As a result, experts are telling us that a working anchor should be capable of handling 700 pounds where actual loads I measured this summer averaged around 35 pounds. Would you call that over design?

Fortunately, anchor selection is simplified because anchors come in only a finite number of sizes. The difference between the capacity of a 35 LB and 45 LB CQR is about 1200 lbs according to manufacture's tests. That is not fine-tuning. We are not talking wastebasket accuracy here we're talking football field. This difference (let alone the total capacity) is greater than the measured 60-knot static wind load on my 44 ft cutter. In order to select an anchor let's concentrate on failure.

Anchor systems rarely fail because loads are considerably less than commonly estimated, but when they do, the most common failure is dragging. When most people drag an anchor, they instinctively think the solution is a larger anchor. Ninety-nine percent of the time they are wrong. This has led to some ridiculously large anchors on some very small boats. If I were dictator of the world, I would imprison people for saying, "get the largest anchor you can carry."

Practical anchor selection is based on two facts. First, any cruising boat, even those who cruise locally, is subjected to anchoring in harbors with a broad set of bottom conditions. Second, selecting the wrong anchor for a given set of bottom conditions bears heavily on which anchors you have on the boat. That is, if you only have one type, then the chances of failure are greater than if you have several.

Having more than one type anchor aboard allows you to match the bottom conditions with the anchor, for example, small sharp flukes of the Luke for hard digging to large broad flukes of the Danforth for soft easy digging. A CQR is handy because it allows extra weight to get through grass and weeds. Other common anchors have different advantages. In normal surface conditions (current, wind and waves), and the right bottom condition any small one of these anchors has the capacity to hold a very large boat. In the wrong bottom conditions, it will take a very large anchor to hold even a small boat.

It should be apparent then that you could approach this problem of variable bottom material strength from two separate points of view. Get a very large anchor and hope it holds or, get several smaller anchors and match the bottom to the anchor. If you agree that small and smart is better, the only remaining question is how small is small.

A time-honored method, which is both simple and valid, is trial and error. Pick up a couple of different anchor types a couple of sizes smaller than recommended. My normal working anchor is two steps lighter than recommended. Another way might be to select anchors for boats ten feet shorter than your boat. Go cruising for a couple of weeks. Using the smaller anchors and the procedure outlined, in the article on anchor use, yuo will be able to estimate the static failure conditions for your boat, that anchor and that bottom material. It may take several summer cruises to test the anchors in a wide variety of bottom materials, but eventually, you will have a pretty good idea of the value of each of these anchor types and where they are best used. As your budget and horizons grow, slowly add a couple of more anchor types until you have an anchor that will match all bottom conditions.

OK, so much for normal conditions, what happens if you are caught in 70-knot winds? Well, if you have a large anchor you can use it, however, a better solution is to put down two or more of the smaller anchors in several configurations. For example, multiple anchors on multiple rodes not only reduces the load on each rode but keep the bow of the boat more into the wind which also reduces the overall loads. When using multiple rodes in storm defense the angle between the rodes should be 45 degrees or less each side of the wind direction. This will reduce the load on the multiple rodes to 30 to 50 percent of that on a single road.

Multiple anchors on a single rode almost never drags because the foremost anchor must be pulled free of the bottom before the second anchor can break out. When using multiple anchors, shackle the crown of the first to the shank of the second with more chain than water depth. Chain is best here since elasticity has very little effect. The long chain will greatly assist in setting and retrieving these anchors. In the real world, the ability to mix and match in the hands of a competent boater is far superior to dead weight or a single anchor system.

Rode

The first consideration in rode selection is the type of rode. The attributes of the two choices, chain and nylon with a short chain leader, are compared in table 1 below.

Table 1 Anchor Rode Comparison

Characteristic	Chain	Nylon
Abrasion	+	
Cost		+
Durability	=	=
Ease of Cleaning		+
Effect on Boat Comfort		+
Effect on Boat Performance		+
Elasticity		+
Fittings	+	
Holding in Light Winds	=	=
Holding in Heavy Winds		+
Placing Primary Anchor	=	=
Placing Secondary Anchor		+
Quiet		+
Retrievability (without Winch)		+
Safety	=	=
Slipping Anchor		+
Stowage of Rode	+	
Strength	=	=
Total	3	10

A few comments about the values in this table need explanation. The durability of both chain and nylon are considered equal because whereas one corrodes, the other deteriorates slowly when exposed to sunlight and salt water. The fittings used to attach or connect chain can be chosen to be as strong as or stronger than the chain whereas the knots and splices used on nylon are at best only 90 percent as strong as the line. If a winch is added, the retrievability "+" changes columns. Both rodes are judged equally safe; nylon rode seems to entrap legs while chain entraps fingers with about equal frequency and severity. Strength is considered equal because strength depends upon diameter, and either material has adequate strength to perform its function. Chain rode, due to its considerable weight, does increase the loads on the boat portions of the anchor system.

Chafe resistance is the most common reason given for using chain. No doubt, that chain is superior in this respect and the thought of your rode chafing through during the night is particularly unsettling. However, consider the environmental damage of thousands of cruisers sawing away on coral heads with their chafe resistant rodes in complete security. I am afraid that this practice is no longer acceptable. The alternative is to anchor so the rode is free of coral; Don Street, others and I have used all nylon rodes in coral for many years. All it takes is a little thought and the proper anchoring procedure.

Once rode type is selected, practical selection of rode diameter is a no brainer. If you prefer nylon, it turns out that a 3/16-inch diameter line is strong enough to hold my 44-foot cutter in a wave-sheltered anchorage in 60 knots of wind. But, who among us want to pull on a 3/16-inch line? By the time you select a line of reasonable size for handling, 7/16 or 1/2-inch diameter, the load carrying capacity is sufficient for everything except extreme dynamic conditions in hurricane winds.

Resist the temptation to go larger than 1/2 inch. Big is not better in rode selection. As we have seen earlier, larger than necessary diameter lines have less elasticity and actually increase the probability of failure in dynamic conditions. So, forget detailed mathematical analysis just buy 300 feet of 1/2 or 7/16-inch nylon line, your hands will feel better and it is more than strong enough.

If chain is your rode of choice, 3/16-inch chain is over twice as strong as 3/16-inch line. The only time one can get loads above the strength of 3/16-inch chain is under dynamic conditions. The two most common reasons for larger chain are to protect against dynamic conditions and to provide better holding on short scope.

Increasing chain weight to protect against dynamic loads is a very inefficient process. The load on the chain is proportional to the square of the wind velocity; therefore, it is necessary to quadruple the chain weight to double the wind velocity. However, considering that the chain's elasticity depends on water depth, a better solution might be better to use more of a lighter, cheaper chain. The longer chain would allow you the option of anchoring in deeper water during dynamic conditions thus significantly reducing dynamic loads. The less weight in the bow will also let the bow ride higher out of the water, thereby keep the foredeck drier and generally improve overall boat performance.

The belief that the chain's weight helps to hold the anchor shank on the bottom, thereby improving holding especially using short scopes is not completely true. What is true is that in light winds the chain does tend to reduce drift. This apparent stability of position can give the boater a feeling of security. However, feelings and facts are not necessarily the same. As we have seen earlier, once the load gets above 500 pounds or so, composite rodes, due to their elasticity, result in a smaller shank angle than chain.

The Boat

Bits, bollards, bow rollers and the like are relatively simple problems because of their nature. The selection of two or four half-inch bolts to hold the bit in place is small in cost, added weight and space, therefore the impact of selecting a unit design to handle a load 5 times larger than needed is minimal. For these types of components, I suggest you use the ABYC load table. In fact, the table was originally designed for just that purpose, i.e. bit design. The table was later adapted by others for anchor loads.

<u>Windlasses and Capstans</u>

Windlasses however are another matter, it behooves the owner to eschew the ultra safe and sharpen his pencil a bit. Windlasses are generally sold based on various retrieval loads, breakout loads or overall power.

In truth, retrieval loads can be reduced to little more than the dead weight (a depth times weight per foot) by powering the boat into the rode. For example, there are very few times when a boater will want to go forward in the middle of 30-knot wind and ask the windlass to bring up the anchor under its own power. Generally, if any wind is blowing, the engine of the boat is brought into play to assist the windlass.

Breakout loads can also be reduced to minor loads, (slightly more than rode dead weight plus the weight of the anchor), by halting the retrieval process for a few minutes with the rode near vertical and letting the anchor work loose under the action of the boat. In severe cases, the engine itself can be used to pull the anchor free of the bottom.

Loads during setting and use of the anchor should be transferred to bits or cleats and not left on the windlass. If these procedures are followed, the normal anchor loads on a windlass should be less than 100 pounds. Thus, the major load on your windlass may be hauling a two hundred pound deckhand to the top of the mast. The result is that if proper anchoring technique is used, all loads on windlasses are relatively unimportant and other selection criteria need to be used.

Unfortunately, there exists a profusion of statistics generated on windlasses. To avoid the confusion concentrate on power. Power is a measure of the windlass's capability to move a load, over a distance in a given time. In other words, power (P) equals load (L) times velocity (V).

$$P=LV \qquad \textbf{Eq 1}$$

Since the power of a single windlass is fixed, this means when the load goes up; the retrieval speed must go down and visa versa. Cost and serviceability are also related to power. Units that constantly work near their maximum power will fail more often. Whereas the most familiar measure of power is horsepower, it can also be measured in foot-pounds/second or watts.

There are two different types of power involved in windlass selection, power in and power out. Since most windlasses are electrically powered, power in (P_i) is the easiest to find.

$$P_i = EI \qquad \textbf{Eq 2}$$

Where E is the voltage, I is the current in amps and P_i is power in watts. The voltage is relatively constant but the current changes as the load changes. The most useful current is the breaker current. Whereas most breakers used for windlasses are thermal and allow current in excess of breaker ratings, they will only allow it for short periods. Thus, a 12-volt system with a 70-amp breaker has a power in rating of 840 watts.

Power out (P_o) is related to power in by the efficiency of the system. A high average for windlass efficiency is 0.4. Thus;

$$P_o = 0.4EI$$

Where P_o is measured in watts. It is more useful to us to change the power units to ft.-lbs./sec. by multiplying by 0.738. Resulting in,

$$P_o = 0.3EI \qquad \textbf{Eq 3}$$

By relating this equation to equation 1, we can find for any given load (L) in pounds, the retrieval speed (V=d/T).

$$P_o = 0.3EI = Ld/T \qquad \textbf{Eq 4}$$

Where d is the distance in feet and T is the time in seconds.

Table 2 lists the time required to retrieve 300 feet of rode under the working loads for some common windlasses.

Table 2 Windlass Retrieval Times

Type	Breaker	Breaker Power in ft-lbs/sec	Working Load in pounds	Retrieval Time Working Load in minutes	1 min. Load in lbs
Horizon 500	25	221	110	6	35
Horizon Express	70	620	220	4	99
Horizon 1500	70	620	330	7	99
Sprint 500	25	221	110	6	35
Sprint 900	70	620	195	3	99
Sprint 3000	100	886	550	8	142
Powervalue 500	30	266	200	9	43
Powervalue 501	30	266	200	9	43
Powervalue 502	30	266	200	9	43
Lewmar Concept 1	90	797	100	2	128
Lewmar Concept 2	150	1328	200	2	213
Lewmar Concept 3	150	1328	300	3	213
Anchorman 700	70	620	110	2	99
Anchorman 1000	70	620	220	4	99
Anchorman 1200	70	620	330	7	99
Marlin	50	443	330	9	71
Tigres	100	886	660	9	142
Progress	100	886	660	9	142

First, notice in this table that the working load retrieval times are predominantly over 3 minutes. Very few people are going to wait 5 to 10 minutes to retrieve their anchor rode. Instead, they power into the rode and rarely face these types of loads. Thus, the so-called working loads are rather esoteric and useless for comparison. A better rating of windlass power might be a standard one-minute, 150-foot, retrieval load as shown in the last column. This value is calculated from equation 4.

$$L = 0.12EI \qquad \textbf{Eq 5}$$

Remember a minute is a long time and if you are anchoring in 30 feet of water with five foot of freeboard forward that the first 115 feet of the retrieval is just the weight of the chain. The last 35 feet picks up the anchor load as well but gets steadily lighter as the anchor moves away from the bottom. As for the two hundred pound deck hand, fortunately he is not traveling 150 feet. Most windlass have the capacity to get someone up the mast. The time will vary and can be estimated by rearranging equation 5.

Which brings us to the end of system selection and the end of the anchor article series. We have certainly challenged many commonly held myths on anchoring. Some of the major ones are,

1. theoretical methods to determine anchor loads are complex and not too accurate,
2. traditional static anchor loads are between 3 and 4 times higher than actual values,
3. dynamic loads are traditional under estimated by a factor of 2 or more.
4. failure is almost always due to inadequate bottom material strength,
5. anchor strength depends upon proper setting techniques,
6. chain rode in shallow water under dynamic conditions produces extremely high loads,
7. composite rode is more effective than chain rode on short scope,
8. multiple small anchors are superior to a single large anchor.