Masts & Rigging

By Ralf Morgan

Standing Rigging

Careful inspection and preparation of the spars and rigging is essential prior to any voyage offshore. Embarking on the Pacific Cup is an undertaking that is likely to be the equivalent of many years of use for the average boat. To put this into perspective, sailing the Pacific Cup is the equivalent distance as sailing from the Blackhaller Buoy to the Blossom Rock Buoy 679.8 times. Many Bay sailors have not done that in a lifetime. Now, if you decide you are going to sail back too…….

Many aspects of inspection and preparation are common to all sailboat rigs regardless of construction or type. If the owner/skipper has not taken the opportunity to do a careful inspection of the rig in the past three years, it makes a lot of sense to pull the rig and go over it very carefully. There are areas of the rig that can really only be inspected and serviced when it is not under tension. There are other items that are just easier to do on the ground. While the rig is down, become intimately familiar with it. Take some digital photos of key components. Remember that two in the morning during a driving squall, is not the optimal time to gain familiarity with your rig!

1) Starting at the bottom and working up: the first thing to inspect is the actual mast base. This includes both the mast tube and the mast step. On aluminum spars you should be most concerned about corrosion and electrolysis. Excessive corrosion on either the tube or the mast base is an indicator that the mast may not be able to support the compressive loads of a long ocean voyage. As a result the rig may lose tension and become unstable. On carbon spars you would want to look for signs of delaminating in the mast tube. You would also look for any electrical issues that could have caused the step to degrade. This area takes the brunt of all the compressive loads put on the spar by the sails and the standing rigging. Any question of structural integrity should be addressed.
2) As you work you way up the rig, you should be on the alert for any areas of corrosion or delaminating that appear at, or immediately adjacent to, highly loaded sections of the spar. Some critical areas would include:
    a) *Spreader Bases*: Where the spreader meets the mast is an area which comes under a great deal of load. On Aluminum spars one frequently finds Stainless Steel fasteners or other components that have interacted in the salt water environment. The result is corrosion and degradation due to electrolysis. Carbon spars are usually heavily reinforced in these areas, but you should check for any signs of delaminating and/or cracking.
    b) *Shroud Terminals*: These are the points at which the standing rigging is attached to the spar. On Aluminum spars it is very common to have

Stainless plates or strap tangs fastened to the spar. As with the spreader bases above, corrosion is a big concern. Unlike the spreader bases that have a fairly large surface area, the shroud terminals spread the load over a smaller area and are secured with fewer fasteners than the spreader bases. In addition to corrosion, you should look for any signs that the terminals themselves have elongated under load or have small cracks starting at the loaded areas. Make sure the fastener holes and/or clevis pin holes do not show any sign of elongation or cracking. Carbon spars should be checked for stress cracks around any fasteners and also for sign of delaminating at the highly loaded areas.

c) *Sheave boxes* would require inspection similar to section “b” above. We will address sheave maintenance in section 4.

d) *Spreader Tips:* Inspect spreader tips for corrosion. Also make sure that there has been no wear or damage where the spreader tip meets the spreader tube. Be sure that the grooves in the spreader tip that support the shroud are clean and smooth so that they do not abrade the shroud. On boats with discontinuous rigging, be sure to inspect, clean, and lubricate the attachment points. When the spreader tips have been inspected, cleaned and lubricated, apply chafe protection at the tip to help your sails survive the journey. When you put the chafe protection on the spreader tips, be sure that the spreader tips will drain. You do not want to create moisture pockets at the spreader tips. Things will start to corrode and degrade very quickly.

e) Give careful inspection to other highly loaded areas like, but not limited to: the entire gooseneck assembly, vang attachment points, spinnaker pole track, mast mounted turning blocks, winch bases and running backstay tangs.

3) *Lubrication*: Regardless of whether you have Rod, Wire or Fiber rigging, lubrication of the shroud terminals where they attach to the spar and/or spreader tips is critical. All rigs move. Making sure your shroud terminals have the ability to articulate freely as the mast moves is the single most important thing you can do to reduce the possibility of standing rigging failure due to fatigue. If the terminal itself cannot articulate to line up with the load, the wire, rod or fiber will bend in order to align itself. The end result is point loading and cycling where the shroud meets the terminal. If you want a graphic example, put a metal coat hanger in a pair of vise grips and then bend the coat hanger back and forth. You will be amazed how few cycles it takes before the hanger breaks right where it goes into the vise grip. Use a high grade lubricant like Tef-Gel, Lanocoat or Permatex nickel-silver antiseize.

4) *Sheaves & Sheave Boxes*: Inspect and lubricate all sheaves, sheave bearings and sheave axles. Make sure that the sheave does not wobble on the axle. If it does, either the sheave or the axle is worn out. Replace the worn components and lubricate. Remember, all halyards have some degree of

elongation. As they elongate, the sheaves need to be able to turn freely, or the halyard will chafe on the immobile sheave. Make sure the sheaves are smooth anywhere they will be in contact with the halyard. Also make sure that the walls of the sheave box have not been scored or worn away from abrasion between the sheave and the box wall. It may be necessary to insert thin Teflon or UHMW spacers to fill any voids that have been created.

5) *Cotter Pins*: Make sure that all cotter pins are securely in place. Either tape the ends or coat them with silicone sealant to eliminate the possibility of snagging or chafe.

6) *Electrical*: A lot of this will be covered in the electrical section so we'll review a few basics. First of all, simply replace any light bulbs that are on the spar. This is easy to do while it is on the ground and a pain later on. Check, clean and then seal any electrical and electronic connectors. Make sure that there are no signs of abrasion where wires exit the mast wall. If you find abrasion either replace the wire or, if you determine that the electrical properties are not degraded, put chafe protection on the abraded part and seal it from moisture intrusion. Make certain that the strain from the height of the mast is not carried by the wires or connections.

One final general rule: Many more rigs have failed from being tuned too loose than too tight. A loose rig will move around more and dramatically increase the fatigue cycles. If in doubt, snug it up. *Also, be aware that when you let the backstay off going downwind, the headstay will become very loose. As the headstay loads up, unloads, and flops around it will be an excellent candidate for fatigue-induced failure. Definitely find a way to snug up the headstay either with a flopper stopper type device or by winding up the headstay turnbuckle for the downwind portion of the race.* Pay careful attention to the tuning section.

Wire Rigging

Typically, wire standing rigging is built using one of two alloys in a 1x19 wire construction. Prior to the mid 90's most of the wire was built using alloy 302/304. While it was very strong, this alloy was prone to corrosion and was somewhat brittle. The corrosive properties of the wire often caused swage fittings to crack because the wire expanded as it corroded inside the swage. During the 90's the transition began toward using type 316 Stainless Steel for standing rigging. This alloy while not as strong initially, actually performs better over time because it does not corrode and is more ductile. Since the transition to type 316 wire, the problem with cracking swages has disappeared when the swages are applied within manufacturer's tolerance.

The wire manufacturers tell us that the useful life of a 302/304 rig is right around 7 years. The useful life of a type 316 rig is in the neighborhood of 10-12 years. In most cases you can determine if your rigging has been built using type 302-304 stainless by looking at the swage fitting. If it has a 4 followed by a dash and then the wire size in 32'nds it is most likely type 302-304. Most current standing rigging swage fittings do not have an alloy indicator since they are almost universally type 316.

If you are unsure of the age of your standing rigging, or it falls outside the useful life recommendations it is highly advisable that you replace it prior to venturing offshore.

Generally speaking, swage fittings will handle fatigue induced by rig movement better than mechanically applied fittings like Norseman or Stalock. The longer length of the swage gives the wire a more effective lever arm with which to articulate the terminal. Therefore, the likelihood of bending where the wire exits the terminal is reduced.

Regardless of construction or type, all wire terminals should be lubricated where they attach to the mast. Following are some tips for lubricating some of the more common terminals:

1) Marine Eye terminals are the most common. They should be lubricated where the clevis pin goes through the terminal. In addition, if the eye attaches to a strap tang, the strap tang should be lubricated where it attaches to the spar. If the marine eye happens to be at the top of the headstay, it is prudent to have a strap toggle between the marine eye and the masthead fitting. This will allow the wire to articulate not only fore and aft but also side to side as the headstay pumps in the puffs and waves. If you are using a toggle at the top, the toggle also must be lubricated at the mast attachment pin.
2) T-bar type fittings are fairly common for side shrouds and running backstays. They should be lubricated from the 90 degree bend of the T-bar up to and including the shoulders.
3) Stemball type swages usually go into specially machined receptacles in the spar or into machined sockets in the spreader base. Sometimes these Stemballs are seated using cup washers to provide additional bearing surface. The base of the Stemball must be lubricated; if a cup washer is used, the cup washer should also be lubricated where it will bear against the machined seat.
4) Threaded Swage Studs are most often found going into the turnbuckle. Regardless of where they are used, the threads should be lubricated. The threads on the lower part of the turnbuckle should be lubricated as well!

Rod Rigs

As wire standing rigging has evolved, so has rod. When the first rod rigs came out the issue of fatigue was not well understood. The early fittings did not include components that would give the rod itself any leverage over the terminal. Today, all rod rigging terminals have some sort of strain relief incorporated that gives the rod extra leverage to articulate the terminal. As a result, the life expectancy of a rod rig has increased dramatically. In all honesty, we do not know how long a well maintained and well lubricated rod rig will last. The key words in that last sentence are Well Maintained and Well Lubricated.

All rod is terminated using a “Cold Head”. This technique creates a specially shaped mushroom head on the end of the rod. This head then sits in a seat of some sort. That seat either slides or threads into the actual rod terminal.

The first thing you should do if you have a rod rig is to check for any alignment issues before you pull the mast. One of the critical areas of mis-alignment can be at the spreader tips on continuous rod rigs. The rod should have a sleeve that is secured where the rod goes over the spreader tip. This sleeve is pre-bent to accommodate the angle that the rod takes over the spreader tip. If the sleeve is either over bent or under bent, it is a problem. The rod has not been able to align properly and should be replaced. Another common area of mis-alignment is at the spreader base where the diagonal shrouds exit.

Also verify that the rods have been able to articulate freely. Check the fittings both before the rig comes out and once you have it down on the ground. If at either time you find a fitting that is not able to articulate freely, that piece of rod is suspect and should be replaced.

Following are some lubrication tips for common rod terminals:

1) First of all, rod should always be checked for cracks that may have developed at the cold head. If there is evidence of cracking you have two options. If there is enough adjustment in the turnbuckle and if there is no spreader bend on the rod, you should be able to cut off about 1” of rod and re-head it. The 1” cutoff is a minimum because the initial heading causes work hardening that extends about an inch down from the formed head. The rod in this area is usually too brittle to re-head. If there is a spreader bend on the rod or there is not enough adjustment, the rod should be replaced.

    > **Caution:** Prior to the early 90’s it was common practice to dimple the rod terminal at the threaded insert in order to lock it in place. If your fitting has been dimpled, you cannot take it apart to inspect and/or lubricate the rod head. If adjustment length will allow, you can cut off the fitting and replace it. If not, the best you can do is to inject some lubricant. During the 90’s there was a gradual transition toward securing the threaded inserts with Red Loctite. If your rod was assembled using Loctite, you will have to apply heat to break loose the Loctite. Be sure to clean the threads and apply new Red Loctite when reassembling after inspection and lubrication.

2) The rod should be lubricated at the cold head. This means that the rod seat is slid away from the Cold Head. The bearing surface of the head and the bearing surface of the seat should be lubricated. This applies to all the fittings below.
3) Eye Terminals: They should be lubricated where the clevis pin goes through the terminal. If the eye happens to be at the top of the headstay, it is *required* to have a strap toggle between the eye and the masthead fitting. This will allow the rod to articulate not only fore and aft but also side to side as the headstay pumps in the puffs. The toggle also must be lubricated at the mast attachment pin.
4) Navtangs: These are special terminals that have been developed for rod. The original Navtangs did not have strain reliefs incorporated. If you have one of

these original fittings, the rod and the Navtang should be replaced. Navtangs with the new style Stemball should have the cold head lubricated as in #1 above. In addition the Stemball should be lubricated where it bears on the tang. You must also make sure that the entire Navtang assembly is able to rotate freely in the mast. This is critical to maintaining proper alignment. Do not skimp on the lubricant!

5) Stemballs: Stemball type swages usually go into specially machined sockets in the spar or into machined sockets in the spreader base. On discontinuous rod rigs they are also found at the spreader tip cups. Sometimes these Stemballs are seated using cup washers to provide additional bearing surface. The base of the Stemball must be lubricated; if a cup washer is used, the cup washer should also be lubricated where it will bear against the machined seat.
6) Threaded Rod Studs: Like a wire stud these terminals should have their threads lubricated. In addition, you should lubricate the cold head where it bears on the rod seat. For some reason everyone seems to forget this on the rod studs.

Fiber Rigging

Fiber rigging has not been in the general population long enough for us to have a realistic idea as to its longevity. All the precautions that apply to the lubrication of terminals for rod and/or wire would apply to fiber rigging as well.

The one new wrinkle that fiber rigging brings to the discussion is chafe. Some of the fibers used, especially those in the PBO family are highly sensitive to sunlight. The fiber shrouds are usually produced using unidirectional fibers in a plastic sheath. Unlike most high performance running rigging, it is not anticipated that the fibers will ever be exposed to light or UV. As a result, they are not coated with any kind of "suntan lotion". In the presence of most light and UV the fibers lose strength at a rapid rate. Therefore, if you have fiber rigging, one of your biggest concerns would be to inspect it for signs of chafe. If you find that the plastic sheath has been worn through, that piece of rigging should be replaced. If you find abrasion but the sheath is not worn through, you should immediately determine the cause of the chafe, eliminate it if possible, and definitely add lots more chafe protection to prevent light or UV from ever getting to the fiber.

Mast Tie-Downs

Mast Tie-Downs are required on all keel stepped boats participating in the Pacific Cup. The purpose of the tie down is to protect the below decks crew and equipment by firmly holding the mast butt onto the mast step in the event of a rigging failure. A severe knockdown or rolling the boat can turn the remaining lower portion of the mast into a swizzle stick for the interior of the boat if it is not secured. There are any number of ways to create the tie-down. On most boats the owner will probably want to remove the tie-down after the race. One very clean way to create the tie-down is to install small t-bar fittings into the mast a few feet up from the mast step. Then you would install some large pad eyes onto the supporting member of the step. There are several options for connecting the two. The simplest is a T-Bar Swage with wire that slips into the mast fitting and leads to a small turnbuckle that attaches to the pad eye at the step. You can also use a T-Bar runner eye with spliced Dynema or Vectran leading to a tight lashing at the mast step.

Running Rigging

No discussion of running rigging can begin without a discussion about stretch. In the simplest terms, stretch means that the piece of rigging gets longer under load. All materials, including stainless steel stretch to some degree. What differentiates the various fibers on the market today is how, and how much, they stretch under load. There are basically three types of "stretch" or "elongation" that affect modern running rigging.

1) For want of a better term, we will call the first type of elongation "Construction". Unlike fiber standing rigging, almost all running rigging is braided in some fashion. This allows for better splicing and handling. The braid functions like a Chinese Finger Puzzle. The harder you pull, the tighter the braid gets. As the braid tightens, it loses diameter and elongates. Some of this elongation goes away as the line gets used. This causes the familiar experience that a line which was soft and pliable at the chandlery, seems to get harder and harder after each use. Please note that when you splice a line, you are pushing on it to open the braid. This is the reverse of Construction Elongation. You are making the line artificially shorter. It is not at all uncommon for the area around the splice to "grow" an inch or more from the time the line is first spliced until the splice is firmly set under load.
2) The second type of elongation is called "Elastic" elongation. This means that the individual fibers elongate under load but return to their previous length when load is taken off. Shock Cord is an extreme example of Elastic Elongation. Some fibers have more elastic elongation than others. The best way to look at Elastic Elongation is as a percentage of breaking load. For example, basic Dacron Line at 30% of its breaking load will elongate 2.9%. In contrast, at the same percentage of load, a line with a Dyneema core will grow .79%. Or, to put it another way, a 100' piece of Double braid Dacron would elongate 34.8" whereas at the same load percentage a100' line with a Dyneema core would elongate 9.48". When you look at these numbers it is important to remember that the elongation only applies to the "loaded" length.
3) The last type of elongation is the least understood. Most sailors and riggers call it Creep. Creep is a permanent elongation of the fiber that occurs under load. In general terms, if the fiber is loaded to a given percentage of its breaking strength and left there for a period of time, it will experience some amount of creep. As long as the load on the fiber never again exceeds the previously loaded amount, it will not creep any further. So, for example, if the

fiber is loaded to 50% for a period of time it will creep. If the load never again reaches 50%, creep is a non-issue. If the load increases to 51%, there is the likelihood of additional creep. When Spectra first came into the market, Creep was a significant issue. The original fiber was called SK-60. As the Spectra product has been developed, creep has become less and less significant. Each new generation of Spectra has become stronger and less prone to creep than the one before.

In order to make life a little easier when discussing the various fibers we will divide them into two categories, slippery and abrasive.

In broad strokes, the “Abrasive Fiber Group: has always been less prone to Creep and has good Elastic elongation properties. The main draw back to these fibers is that they tend to abrade on themselves as the line goes around sheaves and when the line loads and unloads. Generally, after some hard use, the cores of these lines will look fine on the outside but will show significant “fuzz” when you inspect the interior of the core. These fibers are also more sensitive to UV degradation. Fibers in this family will absorb water. The following fibers fall into this category:

Kevlar	Has real issues with small diameter sheaves. No longer common.
Technora	A Japanese Development that is a bit more elastic, abrasive but better on sheaves
Vectran	Still an industry staple. Good strength / almost no Creep
PBO	Very Strong, Almost no Creep, can’t handle light or UV. PBO lines cannot be stripped.

The “Slippery Fiber Group” started with Spectra, SK-60, and has ever since been tagged with the Creep issue. In the most recent generations of this fiber group, Creep has all but disappeared. This fiber group handles abrasion and small sheave diameters beautifully. One of the great features of this fiber group is that it does not absorb water. The new generations are also stronger and have significantly less Elastic Elongation than the Abrasive fiber group. The bottom line is that that if you take the time to pre-load the later generations of this fiber your halyard or sheet will have less Elastic Elongation; it will soak up less water; it will last longer and generally out perform the Abrasive fibers. The slippery fibers are listed below in order of development:

Spectra	Good strength, reasonable elastic elongation; creep is a factor
Dyneema	Also known as SK75. About 16% stronger than Spectra / much lower in creep.
AS-78	This has the same strength as Dyneema, but even less creep
AS-90	Also known as SK90 is about 13% stronger than Dyneema or AS-78 but has no significant creep.

Following is a basic Elastic Elongation Table at 20% and 30% of breaking load. Also included in the table are the breaking strengths for the core material in 1/4” diameter line.

Fiber Type	Elongation at 20% of Break	Elongation at 30% of Break	Breaking Strength of 1/4"
Spectra	0.70%	0.96%	7,400#
Technora	0.96%	1.20%	8,200#
Dyneema	0.70%	0.96%	8,600#
Vectran	0.78%	0.98%	9,400#
AS-90	0.63%	0.84%	9,700#

One more important note: As of the December 7th 2009 ISAF meeting, Dyneema has been approved for Life Lines. The Actual release follows: During the annual ISAF (International Sailing Federation) conference in Busan, Korea, Dyneema® fiber was approved by the ISAF council to be used as a material for sailing lifelines, meeting rigorous standards yet increasing safety performance. The light weight and stronger lifelines with Dyneema® fiber are a technical advancement in yachting world.

If you are using Dyneema for Lifelines, you will want to read the section on chafe protection below:

Chafe Prevention

Running rigging chafe on ocean passages has been an issue since the first humans decided to venture offshore. Fortunately we now have some better tools to deal with chafe. Even if you do a perfect job lubricating your sheaves and eliminating snags and sharp corners, you will experience some chafe. The important thing is to know where the chafe will occur and take the appropriate steps to minimize its impact.

On a standard double braid Dacron line, the cover and the core each take about one half of the load. That is because the cover fiber and the core fiber are identical in elastic elongation. On the higher tech lines, the core has substantially less elastic elongation than the Dacron cover. (see section 2 above) Therefore the core starts taking the entire load very quickly and the cover is truly reduced to being chafe protection. Cordura is a cover material that has recently been introduced to the market. It handles chafe a bit better than Dacron, but colors tend to fade quickly. If you can live with the fading, it provides a slight upgrade in chafe protection without a significant increase in price.

The good news is that if you use a line with a high tech core, and you do chafe through the cover, nothing is lost. The worst you’ll have to do is to taperthe cover back into the core. You should be familiar with this process before going offshore.

It is good insurance to add extra chafe protection to halyards, especially if they are stripped where they will bear on the sheaves when the sails are up. There are thin spectra covers that work very well for this purpose. Remember, Spectra is a slippery fiber that will stand up well to chafe. Even if your halyard has a Spectra or Dyneema

Core a Spectra cover is a good thing to add. The Spectra covers will work well in any situation where a high heat buildup is not expected.

For spinnaker sheets, especially on asymmetrical spinnakers, there is likely to be a great deal of heat built up as a result of the friction of the sheet on the winch drum. Some of the "Abrasive Fibers" have the ability to resist very high temperatures. The rope manufacturers have successfully built chafe covers using Vectran, Technora, and even PBO. While these fibers may lose strength due to chafe and/or UV, they do not lose their ability to handle very high heat. If this seems strange to you, just remember, it is the core material, not the cover that is taking the entire load. If for instance, on some points of sail, your asymmetrical spinnaker sheet is likely to rub on your new Dyneema life lines, it would be very reasonable to put a Vectran chafe cover on the lifeline in the area(s) where there is likely to be contact.

Underway

Do not assume that if it is fine when you start that it will be fine when you arrive in Kaneohe. Well sailed boats will want a checklist that includes a daily inspection of the standing and running rigging. Almost anyone who had done an ocean crossing has a story they can share about some piece of hear that was on the verge of failure when caught; it's a lot easier to correct the problem before failure and the consequential damage.

Spares & Tools

The following list is a tiny beginning to the spares you should carry:

1) A tested and reliable method of severing the standing rigging in the event the mast fails. A hacksaw with the right blades, bolt cutters of adequate size, or one of the fancy, purpose built cutters will work. Make sure you test it on some scrap rigging.
2) Dynema Core. Carry several sizes and lengths. There is almost no rigging related repair that won't benefit from some Dynema.
3) Chafe Tapes; Lots! Carry a variety they each have their own strengths.
4) Spare chafe cover for your halyards and sheets.
5) Lubricants: At least one can of Dry Lube, a penetrating lube and some Tef-Gel
6) Spinnaker Pole Splint or sleeve system.
7) Wire Cutters and Knives
8) Splicing tools. Learn to do the basic splices. A crisis is not when you want to learn.
9) Basic tools like screwdrivers and wrenches. Carry some open end wrenches and Allen head wrenches that fit fasteners common on your boat. Crescent wrenches

are not the answer. Pretend you are going to repair/replace common fittings and see if you have the tools before you leave the dock! Include a small pry bar.

10) A couple of LED head lamps. Things often do not have the courtesy to break during daylight hours.
11) Hose Clamps You will want the really good non-perforated ones! These can also be part of your spinnaker pole repair kit.
12) Spare shackles in sizes appropriate to your boat's rigging.
13) Some spare cotter pins & cotter rings plus a few common clevis pins.

About the author:

Ralf Morgan grew up in San Francisco and has been actively sailing on the bay since 1962. He has owned and actively raced in Folkboats, Express 27's and now owns an Alerion 28 which he races with his wife, Debra Clark. He has extensive big boat experience and has raced in virtually every Big Boat Series since 1985. Over the years he has worked in many areas of the marine industry. His specialty is rigging and sailing hardware. Ralf lives in Richmond, works at KKMI in Richmond, and can be contacted there.