SPONBERG YACHT DESIGN INC.

FREEDOM YACHTS MAST CRACKING CAUSES AND THE CURE

By
Eric W. Sponberg
Naval Architect

INTRODUCTION

Freedom Yachts and their free-standing masts were built by Tillotson-Pearson Inc. (TPI) from the late 1970s to about the mid 1980s in Warren and Portsmouth, RI. The earlier boats were outfitted with aluminum masts, but from about mid-1980 on, the masts were built of carbon fiber. I was hired as a staff engineer at TPI in March, 1980, and at that time the company was doing the design, engineering and testing for the new carbon fiber masts. By July, the chief engineer left the company, and I became the new chief engineer to carry on with mast development for the Freedom Yacht line. In the course of time, the Freedom Yacht masts experienced circumferential cracking in the exterior surface. Usually, this cracking is cosmetic only and not of immediate concern. However, if left unattended for too long a time (we're talking years, here) the cracking can open up and lead to more serious cracking within the masts. This paper describes the nature of the circumferential surface cracking and provides a procedure to cure the problem.

THE CAUSE

TPI also built composite flagpoles and lightpoles on a rather unique production line, and the new masts were manufactured in a similar way on this same production line. The flagpoles and lightpoles also experienced the identical type of circumferential surface cracking, which, in my opinion, led to the demise of the business because the cracking problem was never corrected. The company spent a lot of money making replacement poles under warranty.

The cracks come from the way the masts were made. The masts (and poles) were made on tapered aluminum tubes called mandrels. The mandrels were positioned horizontally on carriages which held them at the ends, and they were driven by electric motors that turned the mandrels during lay-up and cure. First, these mandrels were wrapped with Mylar release tape so that the laminate would not stick to the mandrel. The very first layer in the layup was a winding around the mandrel of stranded E-glass (regular fiberglass) which was wet out with polyester resin by an automatic impregnator. Then carbon fiber unidirectional tapes were layered on in a precise pattern, again going on wet using another resin impregnator. Finally, a last layer of glass circumferential windings was wound on over the carbon fiber. These glass windings comprised a band of 12 strands that were, in total, about 1¼" wide. The winder advanced at 1" per revolution, so there was a ¼" overlap of the strands from turn to turn. These wound-on layers, both inside and outside, did not have any longitudinal strands to hold them together. The last exterior winding exerted enough pressure on the carbon fiber material to compact it and help with wetting the resin throughout the laminate.

50 OCEAN COURT
TEL: 904-460-9494
ST. AUGUSTINE, FL
www.sponbergyachtdesign.com
32080, U.S.A.
~~FAX: 904-460-9355~~

The wet-out mast was then slid under some cal-rod heaters (like the electric elements on a stove) and heated for about 20-30 minutes, slowly rotating to cure the resin. After the resin cured, the masts were extracted from the mandrel with a hydraulic jack-like extraction device, and then placed horizontally on a gelcoating rack. The mandrels were recycled back to make the next mast or pole. The masts were then coated with dark-colored gelcoat to cover the glass. After the gelcoat cured, the masts went through a multi-belt sanding machine with coarse, medium, and fine grit belts to smooth the surface. This process ground off about half the gelcoat and any other excess resin nodules that might be present. Directly after sanding, the masts went straight through the paint booth for painting. After that, the hardware was installed and they were sent off to mate up with their respective boats.

The circumferential cracking occurs over time with the working of the mast. Because there are no cross-fibers through the layers of glass windings, the gelcoat cracks at the boundary between the gelcoat to the fiberglass windings. They start right between individual fibers of the glass windings, and because the gelcoat is a relatively brittle material and at the surface where bending stress is the greatest, the cracks work their way to the outer surface of gelcoat and through the paint. In the vast majority of cases, the cracks don't go the other way—they stop at the surface of the carbon fiber layer underneath. If you stick a knife blade into a normal crack, you will see that it won't go in very far, hardly at all, in fact. So the cracks are not deep and they do not penetrate into the structural carbon fiber below. So a few minor cracks are of no concern and the masts should be just fine.

The following photographs show what circumferential cracking looks like, as provided to me by a Freedom 39 owner.

Photo 1. Minor cracking on a Freedom 39 mast, spacing about an inch apart.

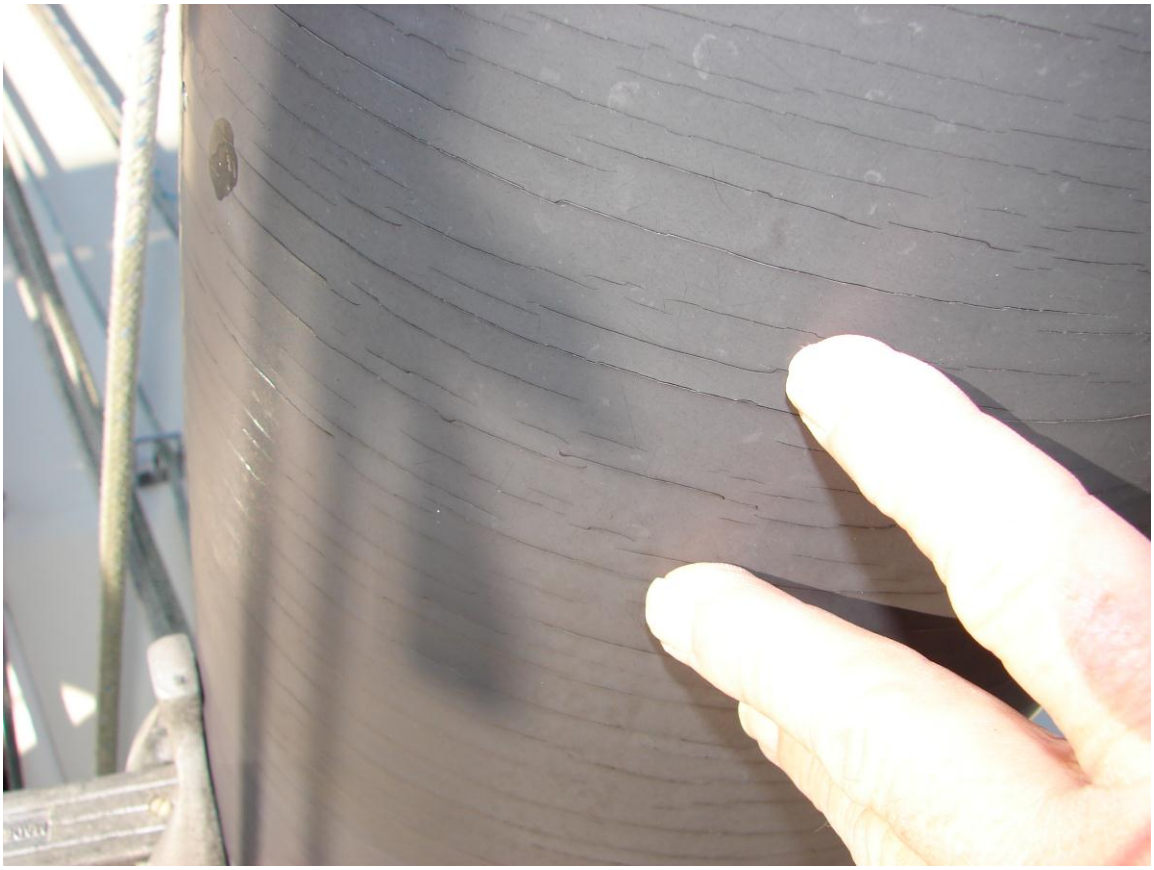


Photo 2. Same Freedom 39 mast near the gooseneck where the bending is more and so the cracks are more numerous and more closely spaced.

THE CURE

In Photo 3 on the next page, a Freedom 21 mast was accidentally dropped during its stepping onto the boat, and where the mast hit the deck edge, the gelcoat was chipped and damaged. I show this photo only to show what the surface looks like under the gelcoat, and how thick the gelcoat can be. However, I have seen instances in which the masts have been heavily used or not well maintained, and the cracking is quite severe and looks pretty deep. The gelcoat can be chipped off with a knife, similar to how this looks.

If the cracking looks bad, then the masts should be pulled from the boat, stripped of their hardware, the surface gelcoat ground off down to the outer glass windings layer, and two new layers of fiberglass and epoxy laminated over the mast for a fresh new surface. This is then sanded down smooth, filled, faired, and the masts can be repainted. This cures the problem entirely.

At the end of this document is a drawing that describes how to repair a Freedom Yacht carbon fiber mast. This was drawn for an owner who had the original wrap-around sails on his 1982 Freedom 40, and he wanted to convert the masts so the single-ply configuration on sail tracks. The cracking had to be fixed first, and so I adapted his drawing for the repair to include in this paper. In this instance, I specified fiberglass socks which are readily available and may make the glass laminating process be a little easier to do. Alternatively, if the glass socks are not available or for some reason cannot be used, then alternately I have specified in the past two layers of 10 oz/sq.yd. fiberglass cloth. This fabric can be wound on in 2”-3” wide tape wrapped around the mast, or in fabric broad good draped around the mast.

Photo 3. Impact damage on a Freedom 21 mast, showing gelcoat and underlying glass.

REPAIR EXAMPLE

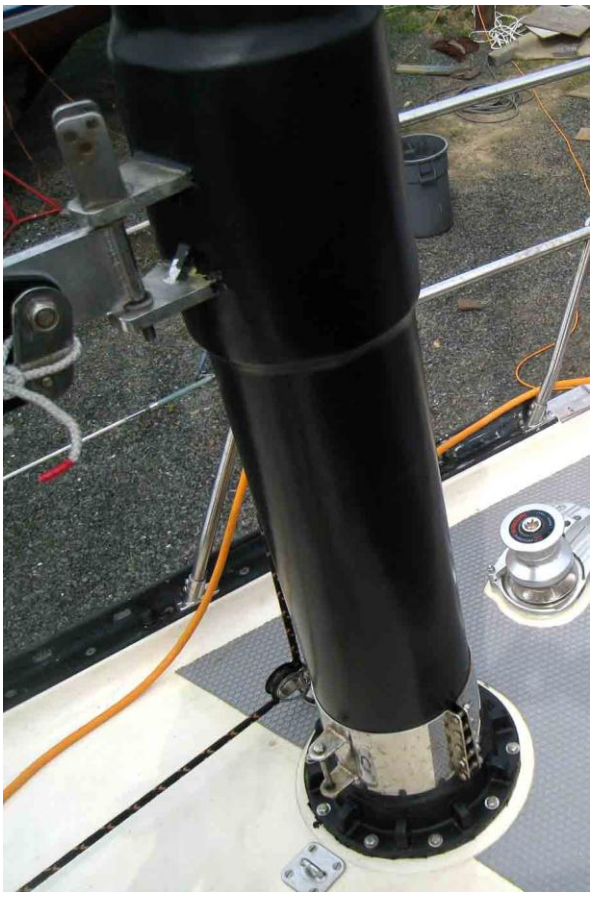
The owner of the Freedom 39 was kind enough to allow me to show some his photographs of the repairs to one of his masts. These show what to do following the same principles in the repair drawing at the end.

If using the fiberglass sock, the fabric is put on dry and wet out with resin, one layer at a time. Let each layer cure. If using cloth, either as tape or as broad good, the mast may be wet out first and the dry fabric wound on, wetting it out again as it goes onto the mast. After the first layer of fiberglass is on, and if the resulting surface is still relatively smooth and still in green cure (after exotherm but not fully hardened) the second layer may be laminated on right away. If the first layer is fully cured (overnight or after at least 24 hours), then the first new glass surface should be sanded with coarse grit sandpaper before putting on the second layer. After the second layer is on and cured, the mast may be sanded entirely again, the surface filled and faired, and then it may be primed and painted with any good quality marine paint system. Two-part polyurethane paints are recommended, as are lighter colors rather than darker colors.


Photos 4 & 5. A fore mast set up horizontally under a temporary tent, supported by an engine repair crane.


Photos 6 & 7. The mast ground down through most of the gelcoat to the glass, but not all the way through. The glass sock put on. This owner used a tube fabric from Giant Leap Rocketry: http://giantleaprocketry.com/products/components_composites.aspx.

Photos 8 & 9. Wetting out the glass with epoxy, with a close-up of the lay-up. This owner bought epoxy from Progressive Composites: http://www.epoxyproducts.com/.



Photos 10 & 11. Painting and installation back on board. The paint was a moisture-cured polyurethane from: http://www.por15.com/CHASSIS-COAT-BLACK/productinfo/CHG/.

CONCLUSION

The circumferential surface cracking as described herein is unique to Freedom Yacht masts as built by TPI. The process for repair offered here corrects the problem entirely provided none of the cracks have penetrated into the carbon fiber laminate. If that is the case, then further consultation is necessary to correct the problem more fully. But Freedom Yacht masts repaired with this specification should last for many more years to come.

The repair drawing follows.

Respectfully submitted,

Eric W. Sponberg
Naval Architect
President
Sponberg Yacht Design Inc.
St. Augustine, FL 32080
Tel/Mobile: 904-460-9494
Emails: ewsponberg@comcast.net or ewsponberg@sponbergyachtdesign.com
Website: www.sponbergyachtdesign.com

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LAMINATING DETAILS

MATERIALS FOR SURFACE LAMINATING:
1. Fiberglass braided sleeves, lightweight, approx. 10.0 oz./sq.yd., 9" dia., will stretch from 11" dia. to 4" dia. See detail at right for laminating notes. Quantity: 200 linear feet.

The fiberglass sleeves are aviailable from two sources below:

Soller Composites: www.sollercomposites.com
Franklin, NH,

and

A&P Technologies: www.braider.com
Cincinnati, OH.

3. Epoxy Resin, Pro-Set 125/224 or 125/226 laminating epoxy, for 20 min. to 40 min. pot life. If different pot life is desired, consult Gougeon Brothers website at www.prosetepoxy.com for advice.

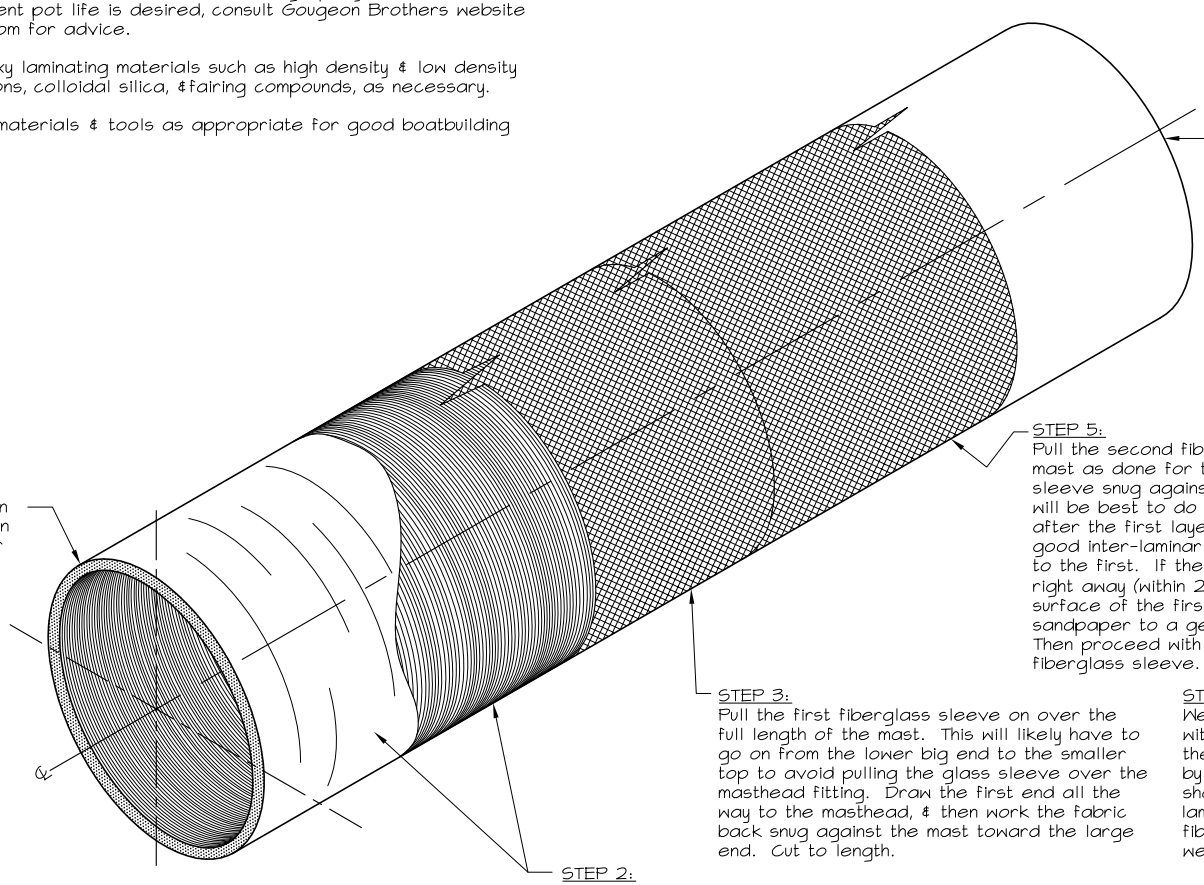
4. Other general epoxy laminating materials such as high density & low density adhesives, microballoons, colloidal silica, &fairing compounds, as necessary.

5. General laminating materials & tools as appropriate for good boatbuilding practice.

GENERAL NOTE:
1. The carbon fiber Freedom Yacht masts built by Tillotson-Pearson Inc. (TPI) have a tendency to crack in the surface in the circumferential direction. Many times, these cracks are minor, very thin & tights, & can be left alone--for awhile. However, they can get worse over time, opening up & curling at the edges, even to the point that the gelcoat underneath the paint can chip off. When that happens, the masts should be repaired.

2. This sheet describes one method for executing repairs. While the job is not difficult, it does take some planning, & it is best done by professional people who are used to laminating fiberglass.

3. The masts must be removed from the boat & brought inside a protected area under a roof & out of the weather. Support the mast on horses horizontally so that it is at a comfortable working level, about waist high. The mast is to be stripped of its outside coating down to the bare fiberglass windings & relaminated with fiberglass & epoxy resin. Follow Steps 1 through 8 here.



Freedom Yacht carbon fiber mast, propped on horses horizontally for relaminating work.

STEP 1:
Remove any hardware from the mast. Fill the fastener holes with high-density epoxy adhesive & let cure. Any other holes or openings that are to be preserved, such as the locking bolt holes at the bottom of the mast, should be filled with bee's wax or children's clay & screeded over or trimmed flush. The new glass sleeves will be laminated over these holes, but they can be drilled out afterwards when the laminating is done.

STEP 2:
Grind off all the paint & underlying gelcoat until the glass hoop windings underneath are exposed. Do NOT grind through the hoop windings which would expose the carbon fiber. The original windings provide a sound base to which the new glass sleeves are to be laminated. Sand the surface of the glass windings smooth so that it is free of snags. Some epoxy resin can be coated over bad snag areas. Let these areas cure & sand again before proceeding.

STEP 3:
Pull the first fiberglass sleeve on over the full length of the mast. This will likely have to go on from the lower big end to the smaller top to avoid pulling the glass sleeve over the masthead fitting. Draw the first end all the way to the masthead, & then work the fabric back snug against the mast toward the large end. Cut to length.

STEP 4:
Wet the entire surface of the glass sleeve with Pro-Set epoxy resin, trying to measure the resin to approximately 50% resin content by weight. That is, the weight of the resin should equal the weight of the glass when the laminating is complete & cured. Roll out the fiberglass with resin & screed off excess well. Let this layer cure.

STEP 5:
Pull the second fiberglass sleeve on over the mast as done for the first layer. Work the sleeve snug against the mast as before. It will be best to do this as soon as possible after the first layer has cooled to get a good inter-laminar bond of the second layer to the first. If the second layer cannot go on right away (within 24 hours), sand down the surface of the first layer well with 60-grit sandpaper to a generously rough surface. Then proceed with pulling on the second layer fiberglass sleeve.

STEP 6:
Wet the entire surface of the fiberglass sleeve with Pro-Set epoxy resin over the second layer in the same manner as the first layer, to the same resin content. Roll out the fiberglass with resin & screed off excess well. Let this layer cure.

STEP 7:
After the second layer has cured, sand down the mast entirely with 60-grit sandpaper. Fill & fair the surface with finishing putty & filler. If the mast is going to be painted with Awl-Grip or equal polyurethane paint, then Awl-Fair fairing compound is suitable. Other paint vendors will likely have similar products. Prepare the mast surface according to paint manufacturers instructions for painting. At this stage, drill out any holes that were filled with bee's wax or clay to re-establish them. Dress all rough edges so that paint will coat properly.

STEP 8:
After paint prep, spray-paint the mast to the owner's choice of color. Oyster White is a popular choice. Paint the mast according to paint manufacturer's directions for high-quality finish. Let cure. Polish out any blemishes as necessary. Once finished, proceed with reinstallation of sail track & other hardware.

FOR ALL FREEDOM YACHTS WITH MASTS BUILT BY TPI

REPAIR OF SURFACE CRACKS IN FREEDOM YACHT MASTS

SPONBERG YACHT DESIGN INC.
50 OCEAN CT. ST. AUGUSTINE, FL 32080, U.S.A.
www.sponbergyachtdesign.com
ewsponberg@comcast.net
TEL: 904-460-9494

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