**Repairing the Repairable .. a WATERS CF WINGMAST**

As many will know by now (if they read the Sept 2022 article covering a Postmortem on the event) … a freak accident damaged my personal W17 *'Magic'*, when a sudden micro-burst of very high wind took it airborne, flipped it, and allowed it to crash down on its mast, bowsprit and rudder, snapping all three in two. Those three 'outer points' took most of the crash load, allowing the tough hulls and beams to survive unscathed. But the mast took a huge shock and was snapped in two when the full boat load came down on it. But unique to this wingmast, it has a central web that held the section intact, limiting the fracture to a short distance from the break, so allowing the mast to be fully repairable to its original strength. With its central web, this mast section is incredibly strong and even resisted the main boat beam crashing directly down on the lower mast piece, with the 5/8" dia S/S mast pivot punching a clean ¾" hole in the mast side wall. Even with that, the section stayed totally intact.

The actual mast break admittedly looked pretty ugly (see pic below), but with the mast section still intact and the damage quite local, I was confident it could be repaired. So here are the details of that work …. in case one day someone else breaks their own masterpiece ;-)

I will divide the process into 5 parts

- Inspection and Clean up
- Alignment
- Rebuild of interior core
- Rebuild of strength skin
- Spreaders
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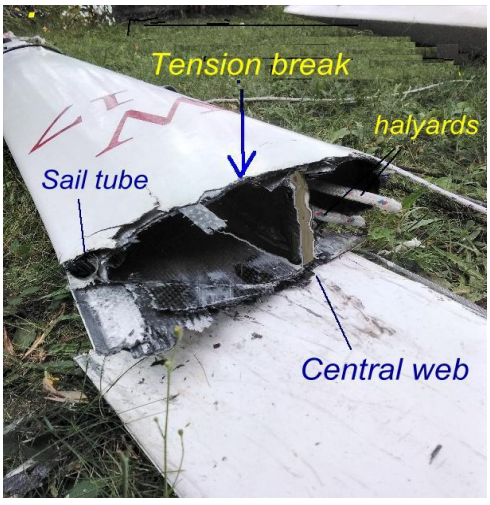
**Inspection and Clean up**




The mast snapped from 450lbs of boat falling on it from at *least* 8ft up (1/2 Beam plus beach clearance), a shock loading that is WAY higher than any possible sailing load.

The port side was in tension and snapped cleanly and an inspection showed a very well compacted and graded skin of 2.5-4mm in thickness which was rewarding, considering it was all built outdoors with hand lay-up and no vacuum bagging. The mast then bent to starboard, flaking the layers that also eventually cracked, but not at one exact height.

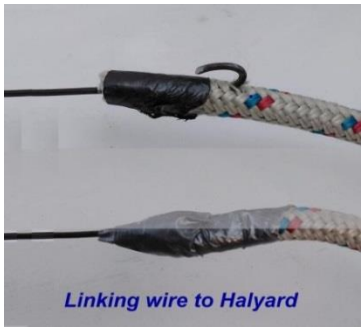
However, even the flaked layers to starboard, only extended about 100mm up from the port side fracture. Both the central web and the sailtube snapped cleanly and very local to the main break point.

Other than the ¾" hole near the mast base where the pivot pin penetrated the side wall and that the spreaders were snapped off by the fall or load on the diamond wires, there was no other damage to the mast. Remarkably, even the FG tube for the steel rotating gooseneck was undamaged, despite taking a blow hard enough to snap off the 5/16" S/S rod (welded to the gooseneck) that sat in the mast tube at the time.

The initial clean up of the damaged area, involved cutting away all damaged layup.

A first cut was made around 50mm back from the break and in only one area was there any indication of delamination beyond that distance .., so that was cut back another 50mm, at which point, the skin was perfectly solid. *(you must always cut back until it's solid).* This was all done with a 30mm metal cutting disc on a DREMEL tool (see pic). A further trimming was done to straighten things up and give a space that would provide good interior access without needing to be too large. The skin each side was cutback significantly more than for the central web or sail tube, so that those two items became accessible to be connected first, once the two mast parts were perfectly aligned.


I now trimmed off the central web square across on both parts and also the sailtube, but did not cut them back more than is justified to find solid structure. You want the sail tube to be closest part when reassembling. I trimmed the sides along the center of the web but only cutting down in depth to the web flange, not cutting into it. I also trimmed off the material at the sides of the sail-tube, leaving the exterior diameter nice and clean. This does take some careful surgery, so support your hands well. The ends now looked like this (left).



I now needed to remove the rope halyards so that they would not accidentally get 'bonded in'. So I attached the end of the halyards to a wire as shown above ..... by feeding a fence wire into the rope center, bending it back over before compressing it in place, and then added tape to create a cone shape that would feed readily through the mast wall guides.

**Alignment**

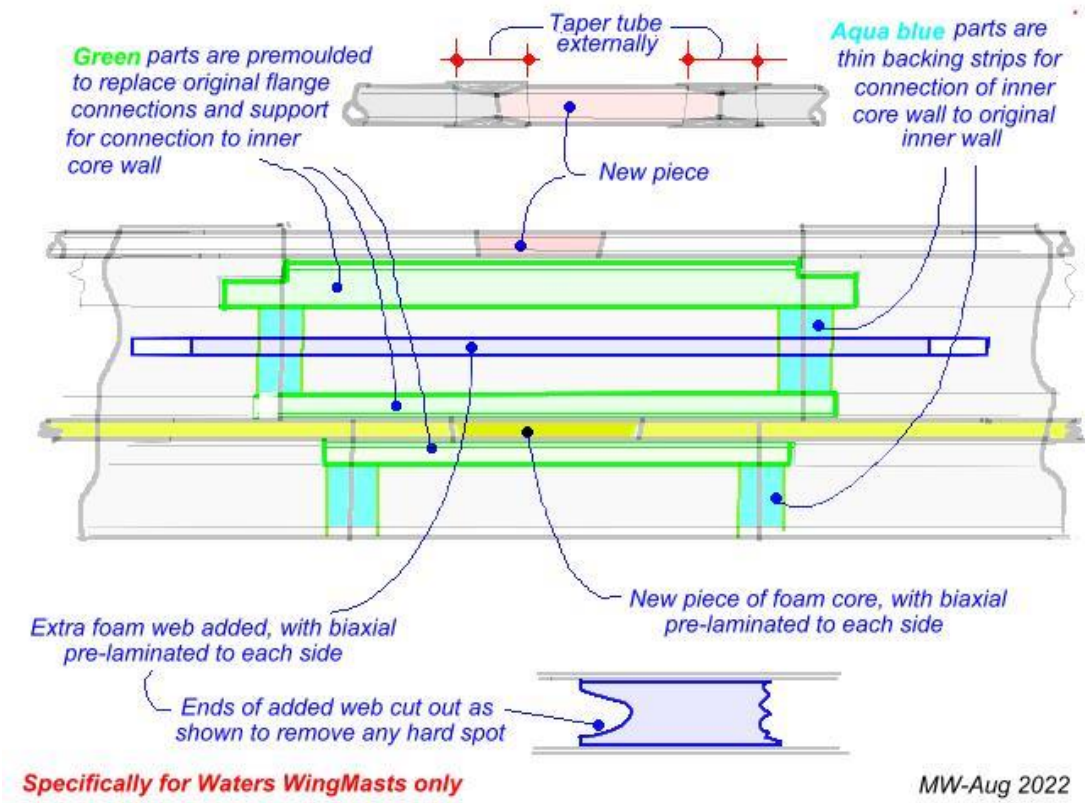
The next task was to set up the two mast lengths in perfect alignment, with the right distance between them so that the missing length of central web and sailtube could be established. To support the 2 mast pieces, I cut 4 plywood parts (5/8" MDO) to fit over either the nose or the tail (sailtube) as well as another 4 parts to use when the mast parts needed to be laid on their side. (Cardboard patterns were made first and checked over the actual mast). Note that all parts were made reversible to accommodate the mast on either sidewall, or vertically with either nose or tail down, and they all have extended end supports for clamping to the sawhorses. Here is what they looked like.

I then assessed what parts I'd need to link the two mast parts and what their lengths would be. This would include several small, thin parts to recreate the inner shell form, plus single cloth backing strips to assure a sound, flush connection to the existing mast.

In summary, these small parts were:

- Short length of 10mm ID fiberglass sail tube, plus fibers to wrap the joint
- Corecell foam strip for web, with biaxial bonded to sides under ply & clamp pressure
- Thin 200gsm. bi-directional strips 40mm wide for web flanges
- Short wood mould to pre-mould 300 gsm V-piece as backing to sail tube and wing parts.
- Nose piece of 200gsm bi-dir (or bi-axial) with flange on each side
- Two wing pieces of 300gsm bi-directional with flange on one edge
- 10 small pieces for backing strips, cut from one cured 200gsm bi-directional sheet
- Secondary added web (if deemed necessary) bonded within wing, with biaxial on both sides of foam (as for main web) and bi-dir flanges on the side.

The length of new parts was determined by what was necessary to cut back to eliminate any crack or flaw in the broken mast. To first rebuild the lightweight (single-layer) 'core' of the mast where it was broken, the assortment of small parts noted above will be fitted where shown in this sketch below. Detailed instructions for each part will then follow.

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One starts alignment with 2 sawhorses under each of the two broken lengths. These should be rugged and rigid so that they will not move easily once placed. Though best to be all the same height, adjusting pads can always be added to a lower support. Once pads are placed, hot glue their base so that they stay in place.

Start marking on the mast (see vertical green tapes in photo), a distance apart that will give you the original mast length. (It was 3ft in this case). Then place the two mast parts in the vertical supports, with the nose down, respecting the clearance you need to end up with the right mast length or the diamond stays may not fit. The sailtube is the first and easiest part to line-up. First prepare a 2ft (600) length of commonly available 3/8”(9.5mm) FG rod by drilling a small 1/16” hole in the side at one end and then tapping in a small finishing nail. This will convert this (red) rod into a long bolt that you can now slide up from the bottom of the mast.

Arrange the other part of the mast at a height so that this *bolt* just slides cleanly into the upper part.

You will need to sight along the tube to raise the supports to suit. The rest of the mast is brought into alignment by using a 3ft long straight edge, checking under the nose centerline and then on each side by the main web (see pic). You will need to go through this process two or 3 times to get the most perfect alignment. Sighting down the slot in the sail tube will help, but only by getting the sides and nose *also* in line will the mast be well positioned vertically with the nose also perfectly straight and in line.

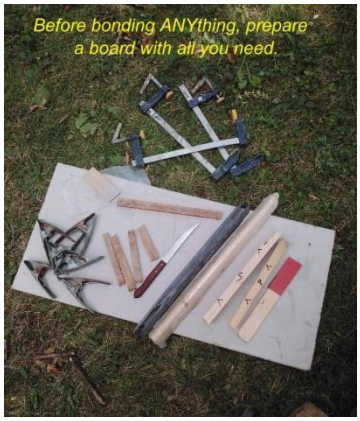
A link to a video introducing this alignment will be added to the intro webpage.

Once you have *triple-checked* the alignment, you can now start the rebuild.

**Rebuild of Interior Core**


Start with repairing the sail tube, fitting the missing piece with the ends cut to a slight bevel so that the piece does not fall down through the opening. Once fitted, remove and grind a taper on the ends of all mating surfaces. Wrap the FG rod with taped waxed paper or plastic wrap and then bond in the tube with the rod holding things in line. Move rod a few times before it's totally cured to be sure it's not bonded in. Then clean up the joints externally and wind a narrow strip of cloth around the tube at each end to fill the tapered area.. Once cured, file off flush.

Next, with a grinder (used *very* lightly) straighten the ends of the existing foam-cored web but also VERY slightly bevel them so that the bottom edges are slightly closer than the top so that the piece to add will not fall through. Then cut a piece from what you have prefabricated, using 10mm Corecell foam core and biaxial cloths both sides (or cloths laid at 45 degrees to act as biaxial) that will close the gap. Once fitted, bond the ends in place with adequate filler, using strips of wood above and below to assure the added piece is totally flush and in-line with the existing web.




The next piece to add is the supporting 'Vee' moulding at the rear of the mast. This not only bonds to the sail tube but also

provides a surface to receive the aft ‘wings’. This piece is pre-moulded around a small wood mould with its angle about 2 degrees greater than the actual angle between the wings. So if the wing-to-wing angle is 18 degrees, then the sides of the wood mould should be 20 degrees. This is to create a piece that will ensure contact of its edges with the wing panels … a sort of spring-loaded back support. This image shows the wood mould being used to position the pre-moulded 300gsm part. The new part has a slot cut each end on its upper edge, to slide in under the existing sail tube and fit up inside the existing wing sides with a good bonding surface.


The next parts to install are the 200 gsm strips of bi-directional cloth to be bonded to the edges of the foam web to convert it into an ‘H’ beam and give it continuity with the existing web. Temporary scrap strips of plywood laid over the flanges will assure the flanges are well bonded at the right angle and stay flat and flush with the existing ones.


At this point, the area will likely become crammed with supports and clamps, so compact finger clamps are best, such as the small steel ones shown in the photo below.


After the main web flanges are installed, it can be a good idea to add in another short secondary web between the regular web and the back tail to help compensate for the damaged part and give the replacement wing wall extra support. As this web will be totally inside the existing mast walls, it’s now essential to sand the inside to be sure the contact is good for bonding., A flat wood strip with 50grit paper bonded on will do this well. See here at right.


Here are the parts needed for the secondary web. A foam core with biaxial cloth bonded on both sides, plus two strips as side flanges Notice that the web has a significant scallop taken

out at each end and also that the flanges are slightly longer. Both these attributes are important to blend in this relatively stiff I- beam to the side wall, without creating hard spots at the mast wall.

Before the flanges are bonded on, it's important to make a trial fit so that this added web fits snuggly at the height (position) you want …. about ½ way between the main web and tail vee and parallel to both. Once the flanges are bonded, this web is bonded in place at its ends .. and held up into the tail of the existing mast side panels, using wood blocks and wedges up from the main web. See above right.



The last small side parts to add are 8 small squares that serve as backing strips at the edge of the original mast. These are simply cut from a pre-cured flat sheet of 200gsm bi-directional cloth. Their vertical dimension needs to close the gap between the web flanges. Best to prepare them all together with small plywood pads to assure even pressure with small clamps. Once in place these will look something like this. Of course, sand out the inside of the existing mast wall first.

Without changing the mast position, one can now prepare to add the wing sides. These are first created on a flat board with a batten at one side to create a 15mm flange along one edge. The two pieces (300 gsm) can be created as one length (ie: at least double the *width of the gap to fill*). Each piece is then trimmed to fit just 1mm inside the existing mast wall, aiming to be flush with the *inside* of the existing mast wall.


To make *sure* this side wing makes a firm, flat contact with the previously fitted Vee piece, it's good to hold this in place with a strip of 10mm thick wood using pan head metal screws, but to ensure the added panel is not pushed OUT by the thread of the screw, its important to drill full-clearance holes in this thin added wing piece. But of course, smaller holes for the *core* of the screw are drilled in the actual Vee piece.

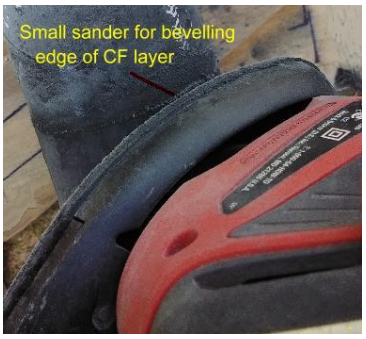
The mating surfaces are now sanded and the wing pieces installed, with temporary screws into the vee piece (only tighten lightly) and clamps around the main web at the lower edge. Note that this wing-piece must lay clear of the existing mast wall

on each side and tight to the backing strips, so that the full space exists to later build up to the original wall thickness … which is indicated in the photo on the mast.

Once cleaned up, the mast is now rotated on the saw horses, bringing the nose uppermost so that the final backing strips can be added under the existing nose after first well-sanding the inside surfaces. See photo at left.

The last inner core piece to add is the flexible nose sheet (200 gsm bi-directional), moulded with 15mm flanges on its sides to keep it straight, that will wrap around the nose from wing to wing, bonded to the above backing strips and the side flanges of the main web.

Once bonded on and cured, the side flanges are trimmed off and the job of grinding down the existing mast wall starts. This wall ranges roughly varies from 2.2 to 4 mm thick, so this needs to be noted so that the grinding effort is properly directed.




One can start near the backing strips, carefully using a grinder but being VERY careful to not even touch the backing strip. Grind with a light touch until the wall thickness above the level of the backing strips is about 0.5 to 1mm, depending on your comfort & control level. Then switch to a small orbital sander such as *The Mouse* by Black & Decker or something similar, using an 80 grit. Carefully bevel down the existing wall around the nose over a distance of at least 100 times the wall thickness, so if its 2.5 mm at the nose, that mean tapering it not less than 250mm. (On the sides, that distance will be more like 400mm so work with a straight edge in one hand to be sure the skin taper is gradual, straight and fair).

**Rebuild of Strength Skin**


TIP: *As you will be binding up the cloth layers with plastic wrap, there are a couple of things that are worth preparing beforehand to make the tasks easier. First, cut the plastic kitchen wrap up into rolls of about 100mm wide so they are easier to handle in one hand. Just cut through the complete roll with something like a bread knife as you rotate it. Also, you will need small pieces of duct tape. So take a roll of duct tape (typically near 2" wide) and slice off a 1/2" wide strip with either a band saw, or with a fine tooth steel*

*hacksaw, working around the reel of tape. You will find 1/2" wide strips FAR easier to handle and quite sufficient for holding the plastic in place …. not to mention the economy of tape.*

Once your mast is all tapered both above and below the newly added part and you've checked over that surfaces are straight and fair, you start by laying in one 200gsm of bi-axial over the nose, followed by several layers of 3-400 gsm UNI of slowly increasing length, until the nose looks something like this photo, feathering down the upper and lower ends of each layer. Apply peel ply over every 2 wet layers of cloth and then wrap a 100mm wide strip of plastic kitchen wrap around the whole mast section to bed this new material firmly to the initially flexible nose, which will become stiffer and stiffer with each layer, until the final layer is flush with the original mast …. checked with a long metal straight edge.

Now carefully rotate the whole mast on to its side, switching over the supports to the open ones cut for side support. Now repeat the same process for each side, but in this case, after grinding and sanding down the existing mast sides to get a taper of at least 1:100, start adding new 3-400gsm UNI cloth right away, with the initial length only 100mm greater than the new part, and slowly increasing the length of each added piece until the overlap over the existing mast is <u>at least</u> 100 times the thickness, ie: 400mm <u>minimum</u> for 4mm thickness. Before adding a 2nd layer, check carefully for any low spots, mark them with a chalk (see at left) and lay in some micro--balloon filler, as the target is to have the UNI laid as flat and straight as possible. Once dry, very lightly sand the surface level before adding the next UNI and peel ply. Always feather down the cured UNI ends before adding another layer and always use peel ply, overwound with plastic wrap to compact the fibers to the existing sidewall to squeeze out excess resin. My tests have shown I can save 2-4% in weight by doing this and improve strength also.


After two layers, the mast will start to look like this photo at right and then, after the final UNI layers are added (and wrapped with peel ply and plastic wrap), like the photo next page, where the level is being checked with the original mast wall.

To be level, the surface should be lightly sanded and then faired using lightweight microballoons.

Once the final level has been reached on both sides and nose, a final layer of biaxial is laid over the top, using 3-400gsm for the 8m mast. As this material is available in a sleeve, I suggest this is used so that the repair can be fully enclosed with one piece. Buy 2-300mm more length.

First, the sleeve size is determined by the equivalent circumference of a pipe of the diameter size. In this case, the girth is the same as a 6" diam pipe, so you'd shop for a 6" sleeve. *(I get mine from Soller Composites in a neighbor State).* But to put it on cleanly requires some special understanding and preparation, so note this.

As this is a biaxial, if you push the sleeve (tube) up together to make it shorter in length, it will get much wider. So when ready, this is the way to feed it up the mast and over all the obstacles that a once-complete mast will now have. As its far too easy to catch the loose fibers on one of these fittings, you first need to add 'ducktape' over them (see pic), and then wrap the whole lower end of the mast with plastic wrap wound spirally, starting up by the repair and winding downward to the foot so that the tape edges are uppermost.



You can now slightly bunch up the biaxial sleeve and feed it up the mast to lay over the area to be covered. Starting in the center, work the material up and down until it lays flat on the prepared mast surface (sanded but wiped dust free). If you bought the right size, the fibers will be very close to 45/45 deg, and should form straight line spirals around the mast. Once pulled firm and it's laying tight to the mast, tape the top and then the bottom to the original painted mast with duct tape so that it cannot move while you add the resin. To better penetrate the biaxial and not move it out of

line, its best to use a brush with its bristles cut short by almost 50%. You can then ‘stipple’ (dab) the resin on, to work it into the fibers. Once evenly wetted out with adequate resin, wrap the mast in peel ply and again spirally wrap it firmly with plastic wrap, pre-cut into hand-sized rolls about 100mm wide that are easy to handle with a better chance of being laid flat with minimum wrinkles. Once cured, pull off the peel ply and touch up with resin any areas looking a little starved or dry.


Remove the duct tape and sand down the upper and lower edges to blend the fiber ends into the original painted mast.

Finally it will look something like this.

Once initially cured, it’s not a bad idea to apply some gentle heat to this, by covering the mast with plastic cover draped over a wood framework (see lower left) and then adding heat under the mast. Getting about 120F for an hour or so, will help the cure and bring up the strength and rigidity.


Once cured, paste over with fairing compound and do a final light fairing, making sure the fairing compound is thick enough that you do not remove any of the biaxial cloth. Then sand and paint 2 coats of polyester, and except for re-assembly of the spreaders, the job is complete.

**Spreaders**

It’s very possible that the Spreader Tube is cracked at the mast mount or spreader tip …or both. Cut away anything split and buildup the lost length of tube with carbon fiber tows wrapped around a dowel of the same bore as the tube …10mn in this case. Of course, wrap the dowel in plastic wrap to prevent epoxy bonding it in.

The tube can optionally be replaced with a short length of the original kite tube butted to the broken tip, but then wrap CF Tows around the joint as you did for sail-tube joints,

If the spigot in the mast has broken, drill out the old stub and bond in a new length of 3/8” dia fiberglass rod.

TIP to do this. *Start by grinding a flat head on the stub and then drill out a 3/16”” dia hole as shown here. By using a smaller drill to start with, you can angle this drill to make sure it’s very centered. Then by following with a 3/8” drill, the proper clearance space will be created within the hidden tube already built into the mast, so that a new spigot of FG rod can be bonded in.*


Another TIP *concerns the wrapping of the spreader tip with a long tow of carbon fiber.*

*Start with a tow of about 600-700mm in length. While still dry, take a 70mm piece of your ½” duct tape and paste 35mm of it on to each end of the tow, with the fibres spread out flat. Now lay this on a flat board with wax paper taped to it, and wet out the tow … but keeping the ends dry. Now, to wrap this around the spreader, place one end on the spreader tube away from the end, and press down the duct tape. Now you can add some tension to the wet tow as you go to the tip which needs the wrap, winding it spirally around the damaged end both up and down, until the tow is nearly all used and then return the dry end back to the spreader tube. (You can optionally add plastic around the outside for a smoother finish). This will then cure with a good bond and recreate the tube that was damaged.* See photo previous page, where the duct tape ends are clearly visible.

Finally, bolt on the spreader tabs and drop the diamond wires into the removable spreader tips which are slotted and are either of nylon or fiberglass. Tension the wires to pull the mast dead straight but my personal choice is to NOT overtighten the diamonds, Sure, take out all slack and add just a ‘little’ tension to allow for the very slight stretch. I personally like a mast to *bend just a little* so that its material does some work .. but let the diamonds LIMIT the bend, so that the center of the mast stays “within its radius of gyration”. More on this (with a sketch) can be found in an article about Mast Design at:

**https://www.smalltridesign.com/masts/mast-design-01.html**

This set-up reduces unnecessary pre-compression on the mast from the diamonds, leaving them to only work hard *after* the mast has some slight initial bend.

Here is the mast all finished with the spreader remounted … ”truly as good as new”

Few carbon fiber masts have this repair capacity.

*Mike ….. December 2022*