The SHOCK of the OLD

Part 12: PROBLEMS CAN START AT THE TOP

Moray MacPhail continues his series on refining traditional rigs by analysing their components and the loads they bear..

Following neatly on from the last article in W153, the easiest way to attach a stay to a spar is to make a large eye in the end of the wire and loop it over. The wire needs to be one of the more flexible varieties – 7×7 or 7×19 – and located either on a shoulder or on some kind of chock to stop it slipping down the spar. To protect the spar you will need to cover the wire with something like plastic hose, leather or serving. This has to be the cheapest, simplest and most reliable way of attaching a stay to a spar that there is.

Above: *Gaffer racing. Photograph Kathy Mansfield.* **Below:** *Jumpers and backstay looped on to cheeks on a YW 5-Tonner*

Above: *Our sample modern gaffer: the late Ed Burnett's 30' (9.1m) Zinnia*
Below: *This old wooden mast has clearly seen better days but the mastband is capped and it sits on a shoulder; both ensure it stays at the top of the mast.*

The snag is that the loop will take up a much longer length the spar, particularly at the hounds, where you might have two pairs of lower shrouds, a forestay, a pair of runners and possibly a throat halyard strop all coming together at roughly the same point. Plus removing an individual stay requires the laborious removal of all of the stays above it and so might even involve unstepping the mast. Finally, since the stays come very close to the spar where they attach, they need to be fitted some way above jaws or saddles – or outboard of travellers – to avoid them being jammed between the other stays and the spar.

But soft eyes – wire loops – are a reliable way of attaching stays which is often overlooked for no good reason. Strops can also be useful for halyard blocks as we shall see when we get to some detailed stuff on running rigging in several articles time.

And the band stays on

If you don't like loops, a mastband is a good alternative for a wooden spar. You will need a realistic estimate of the total force that you are trying to resist. Adding up the combined breaking strain of all the wires attached to the band will give much too scarily large an answer, because only one of a pair of shrouds will be loaded at any one time.

Looking at our sample modern 9.1m (30') gaff cutter – since you ask, the late Ed Burnett's lovely Zinnia design – at the hounds we have two 8mm (5/16") shrouds each side; a 10mm (3/8") stay for the foresail; two 6mm (1/4") running backstays; and a variety of halyards, all on a mast diameter of 180mm (7"). If we assume that both the lowers on one side, plus the runner plus the forestay are all fully loaded, that gives just over 18 tonnes (tons). But in W148, we calculated a design load – with factors of safety over expected service loads – of 11.4 tonnes for this craft at the hounds and sized

Left: *Another sorry-looking stick but the substantial shoulder has made sure the galvanised mastband has not slipped.*
Right: *A smarter mast with a through-bolted stainless steel mastband but there are signs of slippage and rotation.*

the mast accordingly. So 18 tonnes is clearly over-doing it. Though it would be better to do the proper sums: W146 to W149. For a rough estimate, use 1.5 times the displacement for the load at the hounds.

If the cap fits

The upper mast load was worked out to be 3.2 tonnes. The easiest thing to do here is to cap the top or outboard end of the band and sit that on the spar. Compressive load for spruce is around 40 MPa, so to cope with 3.2 tonnes we need a mast diameter of only 32mm (1¼")! You would be unlikely to taper the top of the mast that much but it does mean that if you can cap the end of a spar, the band probably won't be going anywhere.

However, there are plenty of cases where you can't cap the mastband, so you will need to use one or more of the following: a shoulder on the spar, through bolts, a locating lug or friction. The first three all create a bearing surface onto the wood, so it is a question of how best to do that.

How big a shoulder would we need here? Using 40 MPa again, then the maximum load on a shoulder is:

$$F_{max} = 30 \times D^2 - D - 2T^2$$

where D is the spar diameter in mm, T is the shoulder depth in mm, and Fmax the load in tonnes. So for our 3.2 tonne load, and assuming a mast diameter of 100mm (4") at that point, a shoulder of 5mm (3/16") would give a maximum load of about 6 tonnes, so that works fine. At the hounds, assuming a 6mm (¼") thick band – about as heavy as you would want to make a metal fitting – on the 180mm (7") spar, it looks like it would take just over 13 tonnes.

That's all fine in theory but will it be OK in practice? It assumes there will be enough wood to take the load, but realistically, it is likely that the edges will be rounded off where the wood is cut in. So it's best if the mastband is inset a little to ensure a flat shoulder.

Beware mastbands with a narrow or sharp lower edge, a failing often seen in off-the-shelf cast bands – they can do a fine job of paring the spar down to their inner diameter as they head south.

What about through-bolting?

On its own and based on the shear strength of stainless steel, we would need a couple of 10mm (3/8") stainless through bolts or one 12mm (½") for the upper fitting, and a couple of 16mm (5/8") ones for the hounds. We would also need to check what the load is on the wood under the bolt, the bearing surface being the diameter of the spar times the diameter of the bolt. If the bearing surface needs to be increased, then we can run the bolt through a larger diameter tube, sometimes also used to prevent the

If a mastband cannot be fitted – because the mast has a sailtrack or for other reasons – then large area plates with plenty of screws and a though-bolt or two seem to be what's required

wood being crushed by the through bolts. The snag is that a fitting can either slip or rotate on a bolt.

Or fitting a lug?

Another way to increase the bearing surface of a fitting into a wooden spar is to fit a lug, often cylindrical, inside the band which locates into a blind hole in the spar. I'm not entirely sure what these are properly called, having seen them referred to as cogs, coaks or cokes, but I can see how they might work either instead of or as well as a shoulder or through bolts.

Now to look at friction...

which merits a digression... If you have two surfaces in contact, say a tyre on a road or a paving slab on the ground, the amount of friction between them is a function of the amount of force keeping the surfaces together and how much they resist being dragged along – called the coefficient of friction.

Surprisingly, it doesn't depend on the area of contact. To get a feel for it, imagine a paving slab on the ground. On its own, you may be able to push or drag it along, overcoming the friction resulting from its weight and the coefficient of friction. Increase the force holding the slab to the ground, perhaps by adding another slab, and it will be harder to drag along because the friction has increased.

In the case of wooden spars the amount of friction you can generate is limited by the crushing strength of the wood. So counter to the normal rule, the area of contact does matter because it is that which determines the force. You may recall from W143 that wood is effectively a bundle of tubes; strong along the grain but weaker across the grain both in tension – the wood splits – and compression – the tubes crush.

Dry spruce or red cedar has a crush strength of about 4 MPa (or N/mm^2) and the coefficient of friction applicable to steel on wood is between 0.3 and 0.5. All that means you can reckon on 1.6 N sideways load – 4MPa pressure times the 0.4 coefficient – per mm^2 of contact area before the wood crushes. Tightening the clamping bolts increases the force holding the band to the spar, so the frictional force which will stop the band sliding down the spar which works out at:

Fmax = 0.5 x D x L

where F is the frictional force in kgf, D is the spar diameter in mm, and L is the depth of the mastband in mm. For our 11.4 tonne load and 180mm (7") spar, the depth is 125mm (5").

In theory, that is... In practice it isn't going to work, as the fitting or spar is not quite circular; the wood swells and shrinks, as some of the spar crushes and so on. My experience is that trying to fix mastbands to wooden spars by friction alone is unlikely to be successful.

On spars of material other than wood – perhaps carbon fibre – which can withstand a higher compressive stress, you could use friction on its own and in fact, I have successfully done so. It tends to be that harder materials have lower coefficients of friction but this is easily offset by the much higher crush strength.

What do you do if your mast has a track for a sail? Well you have to move away from mastbands to plate type attachment – as per the photograph above.– which uses a combination of large area plates, through bolts, and myriad screws. And if you are wise you will heed Herreshoff's advice that "the burr of the countersink should be left on the inner surface as this will increase their holding power on the mast".

Next time we'll attach the wires to these bands and the hull and then dramatically raise the tension.

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