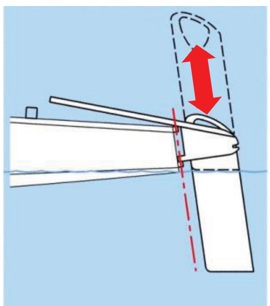
This is the sixth in the series on Paper Tiger control systems for newcomers to the class, or for those who are isolated from the main fleets. The aim is to describe the variations in the way PTs are set up and the possible advantages and disadvantages of the different systems used. It is intended as a guide only. This time we'll examine the rudders.

What Do They Do?

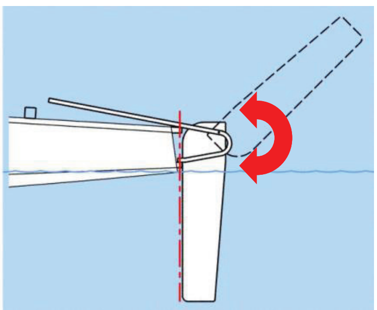
Well, I guess this one should be fairly obvious - they steer the boat. Some skippers also try to generate lift to windward from the rudders when sailing into the breeze (like the centreboards do) but this can create issues which I will cover later.

Configuration

The construction plans show the rudder blades as relatively short and wide (217mm) dagger type blades (i.e. they are raised up and down like the centreboards are) with elastic to hold them down and allow them to tilt backwards if they strike anything. The rudder stocks are made of plywood. The rudders are angled backwards, parallel to the transoms, with the leading edge of the blade set a long way back behind the centreline of the rudder pintles. They are also shown with straight tiller arms. Times have moved on.



By the plans



Current style

Commonly used rudder blades are now longer and narrower; they are usually pivoted with a control system that makes raising and lowering them easier; they are usually mounted vertically; the leading edge of the rudder blade is usually close to being in line with the centreline of the pintles; the rudder stocks are usually made of aluminium or carbon fibre; the tillers are usually bent in towards the centreline of the boat to improve steering and keep them out of the way when hiking behind the rear beam. We will now look in detail at these changes.

Rudder Blades

Generally, a long narrow foil of correctly proportioned thickness is more efficient at steering the boat than a short wide one. A look around the fleets will show a variety of rudder blade profiles of various lengths and widths, but on the "gun" boats they will generally extend around 600mm below the keel. They will be around 200mm wide at the top and often tapered down to a "square cut" bottom.

So what is an "ideal" shape? I guess if that could be answered, "better" shapes wouldn't keep appearing. What matters is that the set-up you have works. If it is similar to what the "guns" are using, it shouldn't be costing you races.

A good test of an effective rudder shape can occur on a broad reach in strong, gusty winds. As the boat tries to accelerate in a gust, it also tries to turn into the wind. If the rudders have to be turned too far to counteract this (possibly due to the blades being too small or of an inefficient cross section) they will cavitate and steering control will be lost. The heavy rudder loads experienced at this time are also sufficient to expose any weakness in the construction of the blades and rudder stocks, and breakage may occur.

Rudder blades are generally constructed from lightweight materials such as balsa, cedar or plastic foam sheathed in fibreglass or carbon fibre. Blades can be home built or there are a few professionally built "off the shelf" versions available. If DIY blades are your choice, pay special attention to the strength of the area around the bottom of the rudder stock, as this is where failure usually occurs.

Rudder Stocks

Rudder stocks are commonly made from square aluminium tube, a combination of aluminium tube and aluminium plate, or moulded carbon fibre.

The tube versions are usually bent to shape and a special bender is required to do this if a "professional" finish is desired.

The tube and plate versions are a simpler cut-and-rivet exercise to build.

Carbon fibre versions need a mould to be constructed and special care taken in the laying up to ensure that weak spots don't occur.

Tillers

The tillers are usually made of aluminium or carbon fibre tube, or may be integrally moulded as part of a carbon fibre rudder stock.

As mentioned earlier, it is common for tillers to be angled in towards the boat's centreline. There are two advantages in doing this:

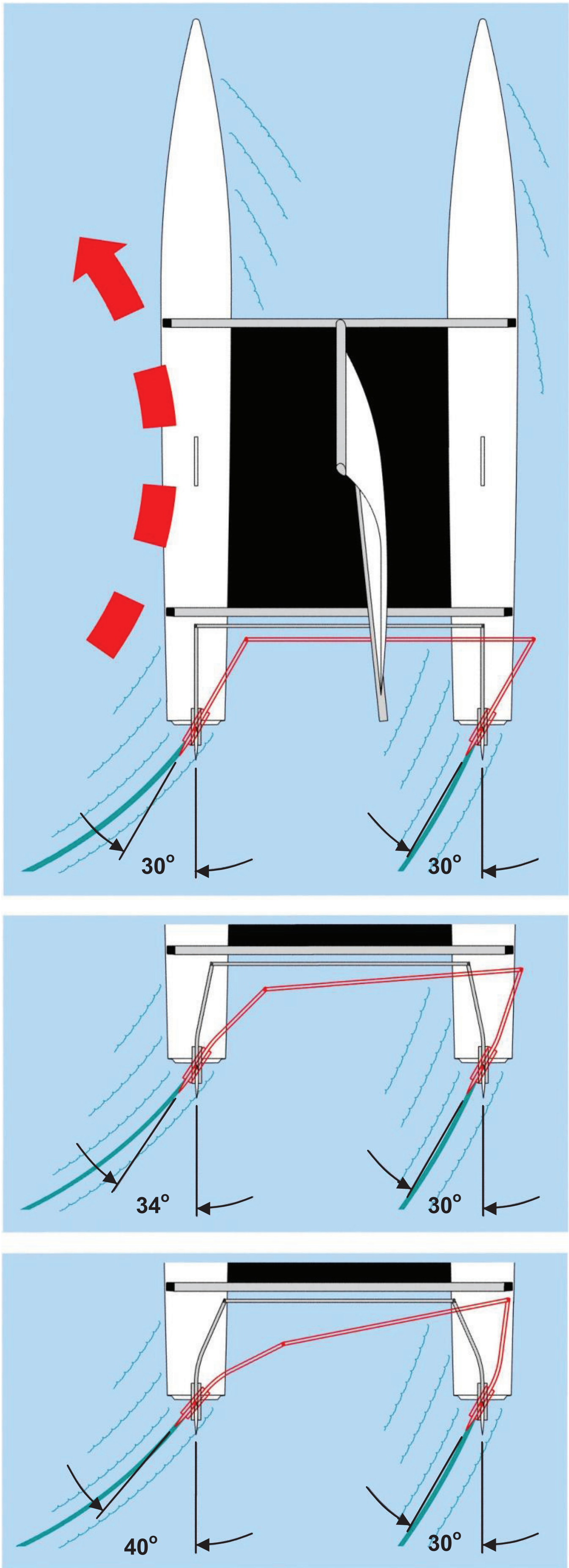
a. When on a broad reach in stronger breezes, it can be advantageous for average weight skippers to sit behind the rear beam to keep the bows from burying. Under these conditions the tillers may need to be pulled significantly to windward during gusts to keep the boat on course. Bending the tillers inwards allows the rudders to be turned more without coming into conflict with the skippers leg.

b. When the boat turns, the hull on the inside of the turn does so on a smaller radius than the hull on the outside of the turn. Therefore, if both rudders are to be operating at their optimum angle (maximum lift / minimum drag), the inner rudder should be turned at a slightly greater angle than the outer rudder. The difference in this angle increases as the radius of the turn undertaken decreases. If the tillers are parallel, this won't occur, whereas if the tillers are turned inwards, this occurs automatically.

So what is the optimum angle? This is not so easy to determine, as a boat doesn't operate on a hard surface like a car does. The "centre" point around which the boat turns, and the amount of side slip during a turn, may vary from boat to boat and in different wind and wave conditions. Therefore, ensuring that there is sufficient space on the rear deck to sit, and that the rudders are able to turn far enough to steer the boat as sharply as the skipper desires, are probably more critical in determining the "right" angle.

The angle adopted is commonly anywhere between half-way between the hull centreline and the inner gunwale, to in-line with the inner gunwale. The more the tillers are bent, the greater the difference between the angle of the two rudders when turned, but the greater the chance of the inner tiller lining up with the tiller cross arm and locking up the rudders when fully turned. A cord attached to the rear beam to stop the rudders being turned too far is required in this instance.

The following diagrams show the effect of various tiller toe-in angles on rudder angle when tacking.



Tiller Crossbar

The crossbar is usually made of aluminium or carbon fibre square or round tube. If the rudder assembly is left on the boat, the crossbar can be attached to the tillers with bolts or stainless pins. If the rudders are usually removed from the boat, the crossbar can be attached with detachable plastic universal joints.

Tiller Extension

Tiller extensions come in all shapes and sizes. In the past, "rabbit ear" types were common (i.e. two extensions rigidly joined and pivoted at the centre). The advantage of this system was that the extension could be pushed aft during a tack or gybe and the other end would be waiting for the skipper when he reached the other gunwale. The disadvantages were the tendency for the tiller to drift away from the skipper if released; the risk of a rule infringement if the leeward end of the tiller hit a leeward boat and the extra weight.

Single extensions are now the norm. They vary from commercially available fixed or extendable versions to home-built carbon fibre, aluminium or PVC tube versions. The advantages of a bendy PVC version are that it can be pulled through under the boom rather than risk having a hand amputated during a gybe in strong winds while passing it astern of the mainsheet traveller, and it is less likely to get bent if snagged, sat on or held onto whilst falling overboard.

The correct length for the extension is a matter of personal choice depending on what is comfortable when hiking to windward and reachable when sitting against the main beam in light weather. Generally it should be long enough to reach the rear chainplates when the rudders are centred, if not a bit longer.

It is important that the extension is comfortable to hold whilst hiking, reaching or sitting inboard and is easily gripped when wet. When selecting the materials to make an extension it is also worth considering the potential for damaging the trailing edge of a raised rudder blade when swinging the extension aft during a tack or gybe.

Rudder Attachment

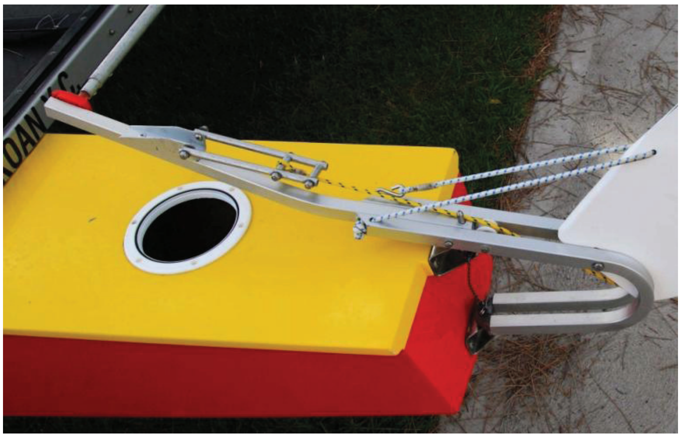
There are numerous configurations for the pintles and gudgeons that attach the rudder stocks to the hull, consisting of commercial or home-built components. The method chosen will usually be determined by the construction of the stocks (see article photos).

What really matters is that they are strong enough to withstand the considerable loads they may be subjected to at times. Generally 4.8mm (3/16") diameter pintle pins are not strong enough and may bend, especially if the rudder stock is allowed to lift at all on the pintle.

Lifting And Lowering

The original rudder blades were lifted and lowered by leaning over the transom and pulling or pushing on the top of the blade. The disadvantages of this were: concentration on racing was lost during the process; the stern of the boat was depressed into the water by the skipper's weight moving aft; the sail may have to be eased in order to reach a leeward rudder, especially in stronger breezes. Generally, lifting rudders killed boat speed but could not always be avoided if floating weed or jelly fish were present.

Over time, pivoting rudders began to appear with controls mounted on the tillers to pull the blades up and down. This was an improvement but still required the skipper to lose concentration and move aft to operate the system. Operating the leeward blade could be especially difficult in windy conditions, with a risk of capsize.



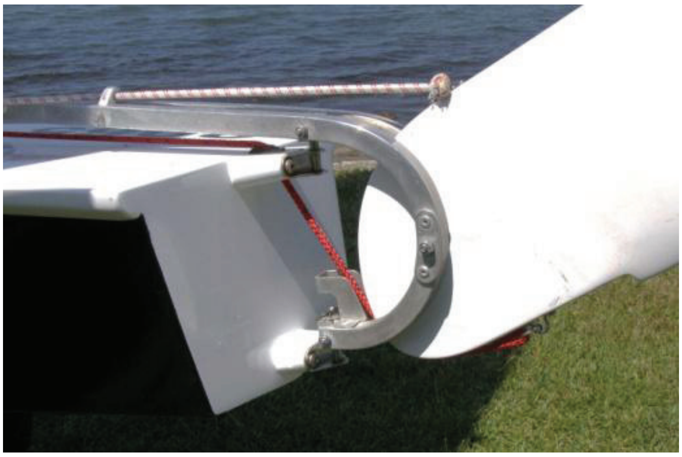
Highfield lever

Push-pull rod

The next step was the installation of a control system that was mounted on the boat, rather than the tillers, and allowed both rudders to be operated from either gunwale with little impact on sailing concentration.

A rudder downhaul rope, attached to the front edge of the blade is guided over the transom through a block and then passes through the rear beam where it is cleated off. The tail end of the rope passes forward to a point where it can be conveniently reached by the skipper, then goes back through an identical system to connect to the other rudder. Each rudder is raised by elastic once the downhaul rope is uncleated.

Tilting cleats outwards helps cleating from other hull



A variation on this system passes the downhaul rope through a tube leading from the transom to the main beam where it is cleated off ahead of the skipper.

Rudder Blade Configuration

Class Rule No. 7 - CENTREBOARDS AND RUDDERS, Part 2 states **"The centreplane of each hull, its centreboard case and its rudderstocks (in the fore and aft position) shall coincide."**

Part 3 states **"The maximun athwartships dimensions of the rudder or rudderstock shall be 80mm within 100mm of the waterline projected from the transom**."

Part 4 states **"The maximum distance from the transom to the centreline of the rudder pintle points shall be 70mm"**

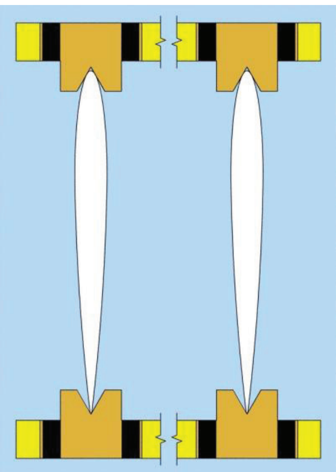
As mentioned earlier, rudders are now commonly mounted vertically rather than attached directly to the transom. This is achieved by making different length pintle fittings or by installing some form of block between the transom and the fitting.

The advantage of doing this is to minimise drag when steering the boat. When a blade pivots vertically in the water flow, all of the thrust generated is sideways. When the blade pivot is angled in line with the transom, some of the thrust generated when it is turned is downwards, effectively trying to lift the stern of the boat out of the water, and this creates drag.

Some skippers notch out the rudder blade so that the leading edge is in line with the centreline of the pintles rather than trailing behind it. This keeps the leading edge of the blade stationary in the water flow as the blade is turned rather than sweeping from side to side, thereby reducing the risk of cavitation when steering sharply (e.g. when tacking). It also increases the leverage of the tiller by increasing the ratio of tiller length ahead of the pintle to blade length behind it.

Rudder alignment

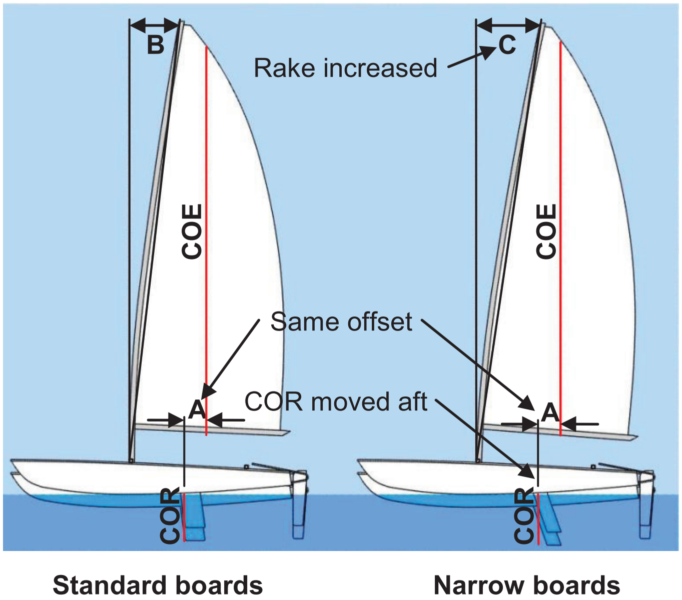
It is important that the rudder blades are parallel when centred to reduce drag. To achieve this on your own, set one of the blades square to the transoms with a builder's or set square. Attach notched pieces of cardboard to a long stick or sail batten, which fit snugly around the leading edge of the rudder blades just below the transoms. Now check if the notches fit snugly over the trailing edge of the blades at the same height. If they don't, the length of the tiller cross-bar will have to be adjusted. Repeat the process, checking front to back until they match.



Rudder Balance

The centreboards are designed to resist the sideways forces imposed on the boat by the sail. To get an idea of these forces, try pulling a board up when on a beat in a decent breeze. These forces also generate lift to windward on the centreboards. Unlike the centreboards, the rudders are hinged on their leading edge. Therefore, if any of this sideways force is applied to the rudder blades, they will turn. This turning force (windward helm) then has to be counteracted by the skipper hauling continuously on the tiller, a somewhat tiring exercise.

The aim then is to create a "balanced" boat with little pull on the tiller. This is achieved by raking the mast/sail until the centre of the sideways forces generated by it (centre of effort - COE) is slightly behind the centre of the hull/centreboard lateral resistance to those forces (COR). This results in a tendency for the boat to turn slowly into the wind on a beat when the tiller is released and generates a very slight pull on the tiller to give the skipper a "feel" for the boat. The boat should barely change course if the tiller is released briefly.



If the mast isn't raked enough, the COE could be at or ahead of the COR causing the tiller to feel vague and the boat to turn away from the wind (leeward helm) when the tiller is released or the bows are hit by waves. This can be very unnerving (and potentially disastrous) in waves and gusty winds.

A few points to note here:

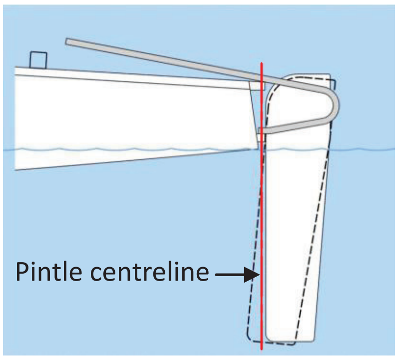
- The centres of effort and resistance can move about

in gusting winds and rough water.
- The size and rake of the centreboards will affect the location of the COR. Switching to narrow boards can actually move the COR forward, compared to standard boards, when the boat is sitting flat.
- The COR moves aft when the windward hull lifts clear of the water but both centreboards are still submerged.
- It is harder to judge balance in light airs as tiller load is minimal, even if the boat isn't well balanced.

Therefore it is best to determine the right mast rake for balance whilst sailing on flat water in a steady breeze with the windward hull just skimming the surface.

Generally, boats with narrow, raked centreboards can carry greater mast rake than boats with wide conventional boards.

Some skippers over-rake their masts, increasing windward helm, to improve downwind performance and try to generate extra lift upwind from the resultant COR loads transferred to the rudders. They compensate for the increased helm load on the tiller by pivoting the rudder blades forward of the pintle centreline to balance the resultant windward and leeward forces acting on the blade. This can be a fine point of balance with this arrangement and the boat can suddenly switch to leeward helm in rough water.



Operation

Some points worth considering:
- Operating the rudders when the blades are not rotated fully down can greatly increase the pressure on the rudder blade and stock, and on the skippers arm. It also increases drag.
- Steering in reverse is the quickest way out of a stall (in irons). Attaching a cord from the rear beam to the tiller cross arm will prevent the rudder stocks burying themselves in the transoms when reversing.
- The rudder pull-down system should have a buffer built into it to reduce damage to the rudder blade, stock or transom if impacting a floating object or the bottom. Some skippers add a thick rubber gasket to the downhaul rope (see photo on page 9)
- Jelly fish can be present at regatta venues and will severely test any rudder pull-down system when impacted at speed. Races can be lost if a blade releases unintentionally.
- If rudder blades (and centreboards) are light coloured, it is easier to see weed building up.
- If an easily accessible system for raising and lowering the rudder blades is installed, it may be beneficial to raise the windward blade to reduce drag. However, this will increase the load on one rudder in strong winds, and also increases the boat length when overlaps whilst racing are an issue.
- To prevent corrosion of powder coated aluminium rudder components, use a sealer when installing rivets and bolts, and flush all components with fresh water after use in salt water.

For further information on PT rudders, refer to the Paper Tiger Catamaran website:
http://www.papertigercatamaran.org/index.php?option=com_content&view=article&id=72&Itemid=87#cboardrudder

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