Worth some effort

2021 will hopefully see the return of the marquee offshore races, Fastnet, Transpac, Sydney Hobart, Chicago and Bayview Mackinac and so on. All these races have stringent safety requirements that are based on the World Sailing Offshore Special Regulations (OSR), with local adjustments such as the Safety Equipment Rules (SER) in the US.

The regulations cover storm sails, crew safety and training, structural integrity and stability. Since the 1979 Fastnet race the regulations to ensure adequate capsize recovery have developed in scope and complexity; ISO has produced a worldwide standard for 'Small craft – stability and buoyancy assessment and categorization'.*

Although this runs to 90 pages the assessment of capsize vulnerability can be captured in a single data plot (Fig A). Plot the yacht's overall length on the X-axis and its range of positive stability on the Y-axis and see where it falls relative to the known capsize casualties. The reality is that this simple plot is really all the data available to assess the offshore fleet's vulnerability to capsize incidents.

The grey triangles show individual boats for which there is reliable data of LOA and range of positive stability, ie the heel angle at which the boat continues to capsize rather than come upright. For a self-righting boat the range of positive stability is 180°. The purple triangles are boats that suffered a knockdown incident but recovered to remain floating upright. The red circles show casualties where boats have capsized and in some cases lives lost.

There is obviously a size effect in terms of a boat's vulnerability to a capsize. The casualties lie towards the left of the graph, and catastrophic incidents are more prevalent in boats with a low range of stability. This is to be expected – whether you're sailing a 10m yacht or a 50m yacht the waves remain the same size. In a 10m yacht the chances of encountering a breaking wave whose height is similar to the boat's beam are relatively high when sailing offshore, while for a 50m yacht you would be in 'Perfect Storm' territory to find a wave 10m high.

This is at the heart of the matter: if you are caught beam on to a breaking wave that is as high as the yacht is wide you could be rolled; after that happens the higher your range of stability the better your chances of coming back upright.

Safety regulators have sought to strike boundaries through this thankfully sparse data-set of incidents to establish 'safe zones' depending on the sailing area. The solid lines on the plot show the limits defined by the UK Government's Maritime and Coastguard Agency (MCA) and the Offshore Special Regulations.

The MCA 'Code of Practice for the construction, machinery, equipment, stability, operation and examination of sailing vessels up to 24 metres load line length, in commercial use and which do not carry cargo or more than 12 passengers' sets stability requirements for unrestricted and Category 1 operation that avoid the known casualties (in red).

The OSR limits defer to the ISO standard which defines category limits based on vessel weight. The limits plotted in the figure are based on an LOA calculated from the boat mass using a typical displacement/length ratio for the ORC fleet. This formulation implies that increasing mass reduces your vulnerability to capsize.

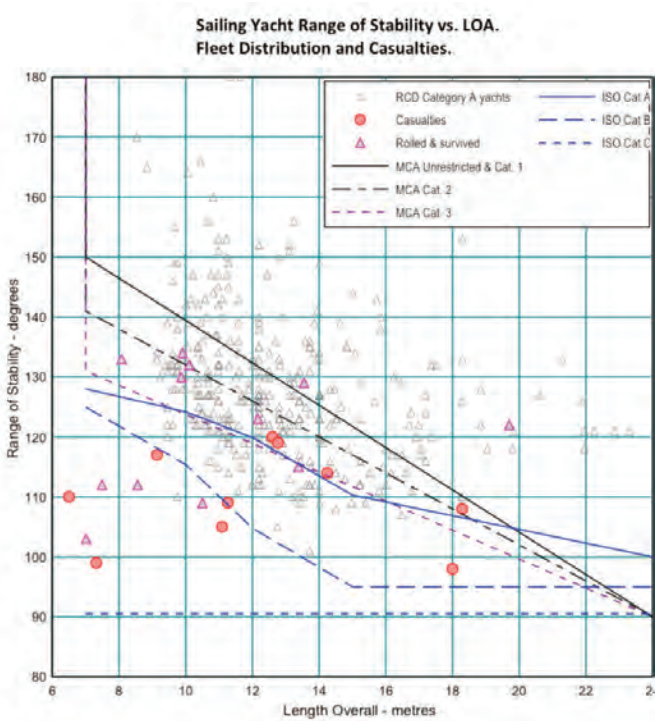
But the experimental work carried out by the Wolfson Unit (University of Southampton) after the 1979 Fastnet race did not find increasing mass much improved resistance to capsize in breaking waves. This work is summarised in Adlard Coles' *Heavy Weather Sailing* which is about to be published in its eighth edition.

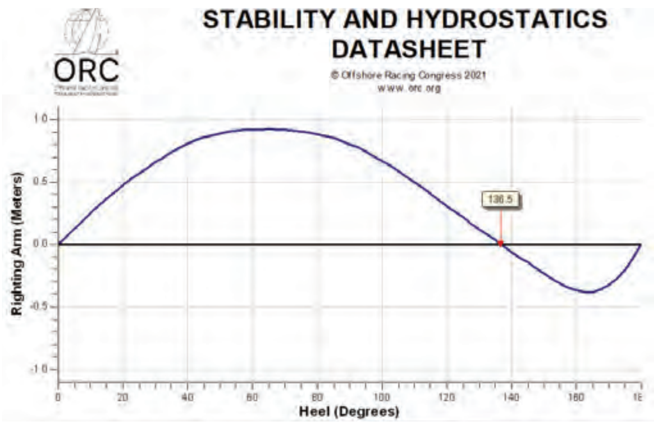
The ISO standard gives a less stringent limit than the MCA. This might be expected because the MCA are looking after paying passengers, and ISO Category A is by no means the equivalent of the MCA unrestricted category. The ISO standard is a product safety standard for production yachts, in the same way that standards exist for road vehicles, washing machines and so on. The standard is set to balance safety against cost and complexity of manufacture. So compliance with ISO Category A does not guarantee your safety on a trans-ocean crossing. Product standards ensure you are tolerably safe on the motorway in a Honda Jazz but you'd be unwise to set off on the Paris-Dakar Rally without some safety upgrades.

Any owner with an ORCi certificate can put his boat on this

ROYAL AUSTRALIAN AIR FORCE/PPL

The luckiest Imoca skipper in history? There were several candidates in the stormy 1996 Vendée Globe – when 'angle of vanishing stability' moved onto the front page. During the 1979 Fastnet race all of the many capsized yachts self-righted, though some later sank. In the 1990s there were too many cases of Open 60s that simply stayed upside down – even after the first canting keels had appeared in the class. This is Thierry Dubois, who after losing his liferaft tied himself to the rudder and clung onto his Nivelt design just long enough to be rescued. During the same huge storm Tony Bullimore would become trapped inside his inverted yacht and *Groupe LG* skipper Gerry Roufs would lose his life when his Finot-designed 'aircraft carrier' capsized and also stayed upside down; Roufs' yacht was still inverted when spotted months later drifting towards Chile. It was also in this race that Raphael Dinelli had his miraculous escape when he was rescued by British skipper Pete Goss as his own rapidly sinking yacht slipped beneath the waves





***Left*: Figure A is a simple plot of overall length against range of positive stability – crudely the 'heel' at and beyond which each yacht will naturally remain upside down. Given the fortunate rarity of such incidents this is most of the data recorded that is available for designers and rule managers to work from. Grey triangles represent popular yacht types; purple triangles are instances of yachts that inverted and recovered; red dots are instances of a yacht failing to self-right (many with loss of life). *Above*: Figure B illustrates the range of positive stability for a generic 46-footer – in this case to a heel angle of 136.5 degrees**

Length-Capsize angle plot. The ORC rule requires that the yacht's hull and appendage geometries are measured, and the freeboard measured to calculate the displacement. Also the yacht is given an inclining test to measure its righting moment. Combining the calculated displacement, the hull geometry and the righting moment the ORC software calculates the position of the yacht's centre of gravity and the stability curve.

The boat shown in Fig B (top right) is 14m LOA and with a range of positive stability of 136.5° it sits well above the safety boundaries. That said, the ORC righting moment curve is not the same as you would get from a full ISO-certified inclining test.

For historic reasons the righting arm curve assumes the boat has a flush deck and no cockpit. This means that a large cockpit that floods as the boat heels and thereby reduces the range of stability will not be captured; also a large coachroof that increases the immersed volume and increases the range of stability will be missed.

But, these considerations aside, the ORC methodology is accurate and consistent. If you want to get a stability curve that includes cockpit volumes, coachroof and so on, the inclining test data does not need to be repeated – you just need to update the geometry file. Also, with careful weight management the test does not need to be repeated very often; as weights are taken on and off the boat the vertical centre of gravity of the boat can be recalculated and the stability curve revised based on the new VCG.

Inclining

Discussions about the value of the inclining test often revolve around two topics:

'The inclining test is difficult, and anyway it's not accurate because…' and

'Why bother with this when I can get data on a boat just like mine and use that?'

Neither of these objections holds water. The inclining test has been part of ship stability calculations for more than a century.

It works for vessels of all sizes from cruise liners to small yachts. It's a simple test to do: pick a calm day and use a shifting weight from side to side, induce a heel angle, measure the heel angle for each weight shift, measure the weights, and that's it. Today you need to have a CAD file of the shape of the boat, and you need to be able to fix the position of the waterplane at the time of the test in that file. Then it is just maths.

Back in the day when the naval architect was working with a planimeter, Simpson's Rule and log tables you had to be very careful about where the heeling weights were positioned so that you didn't introduce errors due to changing trim. Now modern hull design programs just need to know where the weights were at each stage of the process. It doesn't matter if you use the boom, or a spinnaker pole, or weights on deck, you just have to heel the boat.

Also, there is nonsense talked about how much heel angle you need to achieve for an accurate result – the answer is as little as you can get away with. A cruise ship inclining will see the boat heel by a few tenths of a degree, but because you can use a pendulum that's metres long the deflection can easily be measured. A 10m pendulum hung in a stairwell deflects 17mm for each 1/10th of a degree – inclining more does not improve the accuracy of the result. So make life easy for yourself, measure the heel angle accurately, collect plenty of data points and make sure you know the flotation waterplane. Then close your ears to those who may say 'I wouldn't do it like that'.

And the 'Why bother, there's lots of typical data' objection? Yes, there is a lot of data for boats 'just like yours', but how do you know for sure? A quick check through the ORC database shows that for many well-known production boat types there are many variants (for example, deep keels, shoal draft keels etc), so displacement and range of stability can vary by 10% or even more.

If you are serious about safety knowing your boat's range of positive stability is just as important as having non-expired flares, secure keel bolts and so on. Once an inclining test is done the results are of lasting value. Even if you change the mast or ballasting arrangements, provided you keep track of the changes in terms of weight and centre of gravity position a new righting arm curve can, and should, be calculated.

This is exactly how the ORCi system works: during the flotation and inclining test the weight inventory of movable items is recorded; thereafter the certificate can be updated to a new loading condition without the need for a new inclining test.

The OSR acknowledges that not all entrants for offshore races will be able to put their spot on the graph, because only ORCi mandates an inclining test to get a certificate. In these cases they require the application of parametric screening systems based on weights and dimensions. These include the ISO STIX calculation and the IRC SSS. These screening tests were developed over time by experienced designers and safety experts and offer an alternative if an inclining test cannot be done.

However, what they don't do is generate a righting moment curve, which is the key element of accurately assessing the range of positive stability. If a yacht is close to failing these screening tests, then the first step to fixing the problem is getting an inclining test done. The investment is worth the peace of mind. Not to mention complying with the rules.

Andy Claughton, International Technical Committee

** ISO 12217-2:2017* ❑