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Classic Performance: an Alternative View

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The recent series of articles by Ian Ward in SWS, on the performance of classic yachts certainly got me thinking. I found myself saying out loud (to my wife's consternation) "hang on a minute, that can't be right", "why has he made that claim", "yes, but on the other hand..". etc. This article builds on Ian's work and also offers an alternative viewpoint.

Two of his main conclusions, paraphrased from his summary, are:

- Classic yachts can outperform the modern designs when compared on the basis of their fundamental proportions.
- Classic yachts are typically significantly more directionally stable and better balanced than newer designs.

There are many designs that contradict these statements; why is this so? I suggest that the difference in performance and handling of yachts is not attributable to placing them in the two camps of "classic" and "modern". They are a function of far more nuanced design characteristics.

It is generally a good move to start a discussion by agreeing on common terminology. The original articles did not define the terms "classic" and "modern", but we can infer that a "Classic" yacht is one with a long keel that was designed from, or emulates popular designs from, the 1860s to the 1960s. A "Modern" yacht, however, is not what you might think. The original article refers by example and by inference, to yachts with separate fin keels and rudders that were designed from the late 1960s up to only the early 2000s. It does not include many of the newer design shapes popularised this century, such as the full-length chine and the scow bow.

Next, let me compare anecdotally two designs 100 years apart which defy the conclusions in the original article.

The Itchen Ferry is a term that covers a range of designs of sailing yachts built from about the 1860s onwards, for fishing, racing and ferrying on the waters of the Solent in the UK. They were generally around 7m long and look like the quintessential classic small yacht. Were these yachts fast upwind in a breeze? Not really; certainly not be today's standards. Were they easy to steer? Some might have been but many others were utterly dreadful ("hard-mouthed', in the language of their day).

SALTAIRE- A good example of the Itchen Ferry

The other boat is an 8m quarter-ton racing yacht designed in 1974, quite similar in main dimensions and shape to the 1976 Whiting quarter-tonner *Newspaper Taxi* illustrated in the original article. It is a stereotypical distorted IOR-driven design - extremely beamy, hollow waterlines forward, and a separate fin keel and rudder. Yet it was a delight to helm and never broached in the three years I sailed it, in national and international offshore events. The rudder has a vestigial skeg which would have helped, but only a little.

NEWSPAPER TAXI in the NZ 1977 ¼ tonne series - Image J Green

My point is not so much that these two yachts refute the argument; it is that the design features that give a yacht it's handling characteristics cannot be identified just by looking at the boat. To understand why this is so, let's look at the science and some real-world numbers.

Windward performance

How do you compare a Classic yacht with its equivalent Modern yacht? Should they be the same waterline length, overall length, weight, sail area, internal volume, cost? Naval architects non-dimensionalise these quantities (except maybe cost) in order to compare slightly different sizes of yacht. However, that is not appropriate to this argument; we want to see if Classic yacht A is faster or slower than Modern yacht B. Here is an interesting quiz:

Below are the dimensions of three boats of roughly the same length. Try and place them in order of their upwind speed:

Boat	LOA (m)	LWL(m)	Beam (m)	weight (tonnes)	Sail area (m^2)
A	8.1	6.3	2.9	1.25	29
B	8.6	6.5	2.5	4.5	32
C	7.6	7.0	2.4	2.8	17

It's not easy, is it! The answer is, from fastest to slowest: A, B, then C. So which ones are Classic, and which ones are Modern? You might think the weight gives you the answer, but it's not quite the simple. Boat A is the 1974 quarter tonner, boat B is the 1960s long-keel Twister and boat C is the Itchen Ferry.

The keel hung rudder on a Twister

So when comparing on equal length, the two Classic boats are slower upwind, not faster. However, the Twister does provide a more comfortable ride than the quarter-tonner, so perhaps it just feels faster.

Maybe its unfair to pick on length as a metric. Let’s use weight. Here are 4 boats of roughly the same weight:

Boat	LOA (m)	LWL(m)	Beam (m)	weight (tonnes)	Sail area (m^2)
D	10.3	8	3.3	4.5	66
E	8.6	6.5	2.5	4.5	32
F	11.2	7.2	2.0	3.9	41
G	12.8	12.8	3.9	4.4	90

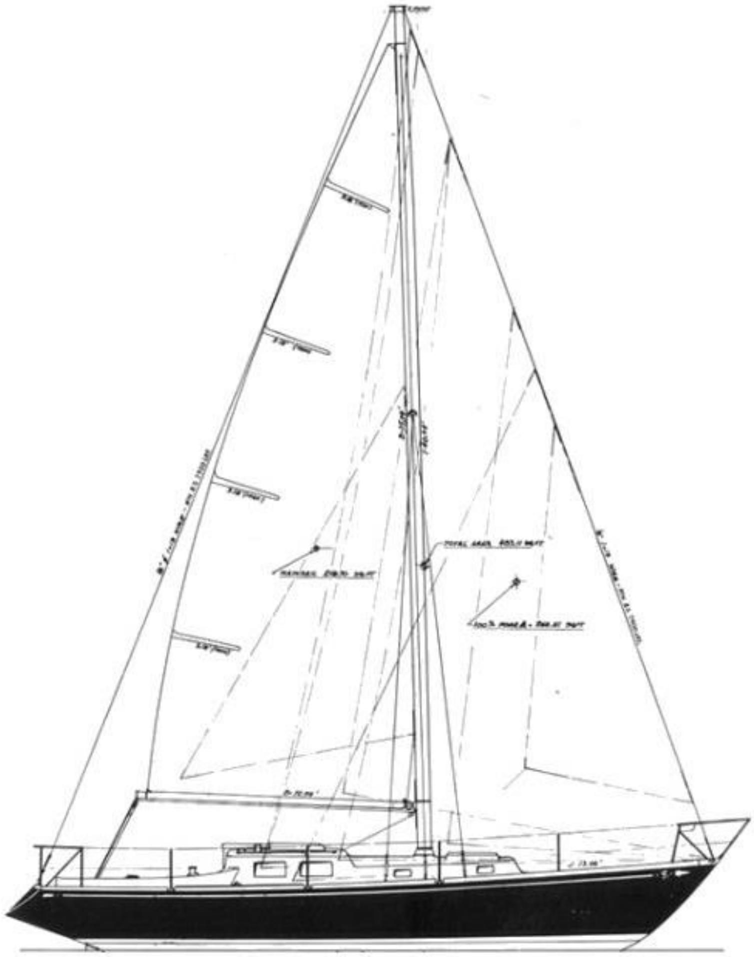
Which are the fastest and slowest upwind?

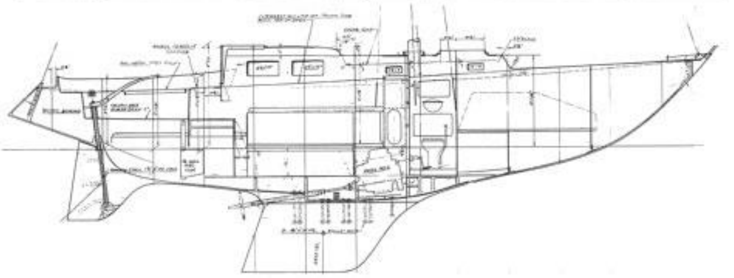
The answer is G, F, D then E. G is a Modern GP42; F is a Classic 6-metre; D is a Modern (1986) Van de Stadt 34; E is the Classic Twister. So, when comparing solely on equal weight, there is no clear winner between Classic and Modern

All we can really conclude from this, is that upwind speed is not related to whether a yacht is a Classic Design or a Modern design. Sharp-eyed critics might claim that the GP42 is too recent to be considered Modern (pre 2010), but it was designed in 2010 so I have sneaked it in.

GP42 Shining Sea

Finally, to truly mangle the definitions, one of the acknowledged upwind performers in offshore racing over the last 50 years is the S&S 34. It is regarded as a classic, but with a small "c' because it does not have a long keel. Therefore it fits into the Modern category of the original article. That's awkward!





Directional stability

The S&S 34 mentioned above handles beautifully (numerous world circumnavigations), yet it was designed by Olin Stephens only two years after he designed the visually similar yacht *Clarionet*, quoted in the original article as “suffering frequent broaches on hard runs”.

To find out what is really going on with the handling characteristics of a yacht, we have to delve into the murky world of fluid dynamics and control engineering.

The original article combines a number of concepts in its description of directional stability, leading to some challengeable statements. The directional stability of sailing yachts has been studied and measured methodically for nearly 60 years (e.g. Spens et al, 1967; Gerritsma & Moeyes, 1973). Directional control is a complex subject learned by naval architects in their second or third year at university, then promptly forgotten by most of them once the exam has been passed.

It is important to agree on what is meant by directional stability. A popular but unhelpful definition is that the boat is directionally stable if the helm is let go and the boat continues to sail in the same direction. This is unhelpful because it is not really the characteristic we are looking for in a yacht. What we really want is a boat where we can lash the tiller in place and it continues in a straight line. The difference between these two scenarios is well illustrated when a boat is towed. What we would expect is that the towed boat would follow the rescue vessel when the helm is lashed. That is my definition of directional stability i.e. it includes the presence of the rudder, but not action of a person steering it. This is called “controls-fixed stability”. If you have ever tried to tow a rudderless boat, you will usually find that it yaws uncontrollably. This is indeed a directionally unstable yacht. To design the boat so that it was directionally stable in this rare situation would require a lot of compromises detrimental to its other handling qualities. We really don’t need to do that. We just want the boat to go in a straight line with the helm fixed in place, which is a much less severe design constraint. How does the designer achieve that “controls-fixed” stability? It is not easy, but the science is quite well understood.

The original article provides a good explanation that the directional stability depends on the relative positions of the Centre of Gravity (CG) and the hydrodynamic centre of pressure (CP). Unfortunately it confuses the centre of pressure with the centre of later resistance (see later), and it implies incorrectly that the positions of these centres are determined by whether the yacht has a long keel, or a fin keel and separate rudder. The keel length has some influence, but it is not a determining factor – there are many different ways of ensuring directional stability.

This magazine is not the place for wading into the world of mathematical imaginary numbers and Bode diagrams that are used to explain the dynamics of directional stability. What might be useful is to reiterate what has been found by numerous towing tank experiments and by analytical techniques applied to sailing yachts (Spens et al, 1967; Gerritsma & Moeyes, 1973; Angelou & Spyrou, 2021): *the length of the keel and the presence of a separate rudder is a very poor indicator of the directional stability of a yacht.*

The balance of a yacht

Yacht balance is all about getting the opposing forces from the hull and the rig to act in line, in such a way that there is no turning effect generated by them. This is different from directional stability, as it says nothing about how the yacht tracks when the helm is lashed.

Traditional explanations of yacht balance start with describing what a Centre of Lateral Resistance (CLR) is, and where it must be positioned relative to the centre of effort (CE) of the rig for a balanced boat. However, a yacht can be directionally stable or unstable without a rig. Therefore the inherent stability of the yacht has nothing to do with the relative positions of CLR and CE. Notwithstanding this fundamental point, the traditional explanations then go on to describe how to find where these two centres are, by taking a profile view of the yacht and measuring the geometric centre of the rig, calling it the CE, and the geometric centre of the underwater profile, and calling it the CLR. Whilst there is nothing fundamentally wrong with defining those two geometric centres, they have nothing to do with where the aerodynamic and hydrodynamic forces act. This is quite easy to demonstrate without getting too bogged down in equations and numbers. Consider a typical fin keel. It is usually a rectangle or a trapezium, and its geometric centre is roughly half-way back from the leading edge. Is this where the hydrodynamic force generated by the keel acts? Almost always the answer is no. The complete answer depends on the angle the keel is making to the water flow. If you bizarrely decided to drag the keel sideways through the water then yes, the hydrodynamic force opposing your effort would be acting at about 50% of the keel length from its leading edge (Hoerner, 1965). However, if the keel is travelling through the water at, say, 5 degrees to the flow, such as when sailing to windward, the generated hydrodynamic force acts at a point only about 20% aft of the leading edge. If the flow is at 10 degrees to the keel, the force moves back a bit to maybe 25% aft (Whicker & Fehlner, 1958). Most yachts sail at a leeway angle of somewhere between 0 degrees and 10 degrees, where we have just shown that the hydrodynamic force is not only acting a point a long way forward of the geometric CLR, but it also moves around as the leeway angle changes. Much the same argument applies to the rig – the true point where the sail forces act is a long way forward of the geometric CE point, and the position varies as the shape and position of the sails are adjusted. Therefore designing a boat with the CE and CLR in line is not going to make for a well-balanced boat. Up until the 1970s, the only way of dealing with all this was to separate the two centres a distance apart by an amount known as the "lead". The amount of lead used by each naval architect for each design was kept a close secret, but it would typically be 10-20% of the length of the boat. That demonstrates just how far out of whack the notions of CLR and CE are for balancing a boat. Indeed, on some boats the amount of lead required is negative!

There are still many yacht designers who use this CLR/CE lead method to balance a yacht, and it can work well if they are applying it to a similar design to a previous one where they got the balance right. However, there are now many much more robust and versatile scientific methods of determining where the sail and hull forces really act, offering much more certainty in creating a balanced boat (Keuning & Vermuelen, 2002). That's not to say that modern methods are anywhere near perfect – there still some modern designs out there that are shockingly out of balance.

It is worth pointing out that many other explanations for achieving a balanced yacht that have been offered over the years are false. For example, the original article makes reference to an obscure 100-year old technique for designing well-balanced boats, called the metacentric shelf theory. It is rightfully obscure for two reasons. Firstly, it was demonstrated long ago to have no scientific basis (Barnaby, 1950, Garrett, 1988)). Secondly, even the designers who used it found that some of their designs were still badly balanced. In other words, it shouldn't work, and consequently it often doesn't work.

The balance of a rudder

The balance of the yacht (discussed above) and the balance of a rudder are two quite distinct features which often get muddled up. There is a good reason for this. Firstly, note that a boat which is poorly balanced requires a large rudder angle to keep it going in a straight line, whereas a well-balanced yacht requires less rudder angle. Next, note that a well-balanced rudder will not require any significant effort from the helm, but a poorly balanced rudder will feel progressively heavier on the helm as more rudder is applied. Therefore a well-balanced yacht will feel light on the helm, even if the rudder is not well balanced. And a poorly balanced yacht will feel heavy on the helm if the rudder is poorly balanced. But a poorly balanced yacht will still feel light on the helm if the rudder is well balanced. It's no wonder people get rudder balance and boat balance muddled up. Let us return to my original example of the Itchen Ferry: we cannot tell whether its reputation for being hard-mouthed (difficult and hard work to steer) was due to the rudder being badly balanced or the yacht being badly balanced, or both.

The balance of a rudder determines the amount of effort required to turn it to a given angle. The rudder force acts at a point called the centre of pressure (CP). If CP is a long way behind the rudder stock (the pivot axis), it will require a lot of effort to turn the rudder. If the CP is close to the stock, it will require little effort, making for an easy boat to steer. If the CP is exactly at the rudder stock, no effort is required to turn the rudder. This sounds perfect, but it gives the helm no "feel" – the rudder just goes to whatever angle it is put, and stays there. If the CP is forward of the stock, things get nasty because the rudder tries to take over, and considerable effort is required to stop it slamming across to its stops (Klaka, 2020).

So the ideal balance of a rudder is with the CP just a bit behind the stock. Why can't designers always get this right? There are two reasons. Let's consider a simple spade rudder to start with. Firstly, the CP is not at a fixed position, it moves aft as the rudder angle increases (Comstock, 1988). This makes a nicely balanced rudder at 2 degrees helm turn into a heavy helm at 15 degrees. The second reason for not getting it right is that estimating the position of CP is still a bit of a black art. The shape of the rudder in all three dimensions affects not only the position of CP, but how much its position varies as the rudder angle changes (Molland, 1978). For example, the CP on a low aspect ratio rudder of a typical 1970s cruiser-racer moves around much more than the CP on the high aspect ratio rudder of a more recent and racier design. This makes it more difficult to make the low aspect ratio rudder well balanced.

Considering skeg rudders, things are a little easier to get right because the skeg generates a lot of the steering force, putting less load on the helm. However, it is still quite tricky to work out where the CP is, because the effect of the skeg varies with what is called the inflow angle (Kerwin et al, 1972). The inflow angle is the same as the leeway angle when sailing in a straight line, but when the boat is turning it is much larger. Thus the skeg rudder may be nicely balanced when turning but not when straight-line sailing, or vice-verse.

Finally, look at rudders hung off the back of a long keel. These act a bit like a rudder attached to a very long skeg. Most of these rudders weigh quite a lot (as distinct from many modern spade rudders which can sometimes be light enough to be buoyant). If the rudder post is vertical, when the boat is upright and the helm is applied, the weight of the rudder has no effect on the weight of the helm. However, when the boat is heeled, the weight of the rudder tends to turn the rudder away from the centreline. This feature can be used to advantage to counter any hydrodynamic imbalance. However, many long keel yachts have a rudder post angled forwards at the bottom. In this case, when the boat is upright and the helm is applied, the weight of the rudder tends to bring the rudder back to the centre, creating the same feel as a badly balanced rudder. When the boat is heeled, the geometry is such that the effect diminishes. It's no wonder there are so many badly balanced rudders out there!

In conclusion, I hope I have demonstrated that Classic yachts are no faster or slower upwind than Modern yachts, and that they can be just as difficult or easy to steer. I suggest that the view of Classic yachts being faster and easier to steer than Modern yachts is not scientific but cultural. We collectively have a tendency to regard new developments with scepticism, looking for their disadvantages even where they do not exist. This is illustrated by the following anecdote, albeit more to do with structural design than hydrodynamics. A very long time ago I was in the boatyard talking to a retired marine engineer who had hauled his 35 -foot long keel yacht out for maintenance. Knowing I was a budding naval architect he imparted what he though was wisdom to me. “Look at that boat” he said, puffing his pipe whilst pointing to the modern fin keel yacht hauled out next to his. “It’s completely unsound to separate the keel out like that and hang it from the hull with a few bolts. It’s much too radical a design for offshore sailing”. The boat in question was an S&S 34 – now considered to be one of the world’s most successful and safe offshore sailing yachts. He had identified a potential problem but was in denial about the possibility of there being a good engineering solution. He has long since gone, but I dare say he is chuckling sarcastically from above as he observes the unacceptably high number of fin keels that have fallen off over recent decades. “Told you so!”, he’d say, still puffing his pipe. But he’s still wrong. Those keels fell off because their design or manufacture was not fit for purpose, not because a fin keel is unavoidably weak. That’s a debate for another time.

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