ISSUE 174
NOVEMBER 2016

Uncovering the Superyacht Market with Opinion, Analysis, Insight & Real Journalism, The “New” Superyacht Report coming soon ...

eryacht

LEDGE • IDEAS AND EXPERT INDUSTRY ANALYSIS

REPORT

INSURANCE
How can operators alleviate perceived risk in their cruising itineraries?

FINANCE
The industry’s leading experts outline the terms and availability of superyacht finance.

LAW
Does the Common Reporting Standard pose a threat to traditional ownership structures?

SECURITY
Cyber security may be the hot topic in asset protection circles, but how real is the threat?

Are we learning anything?

Dickon Buckland, a principal research engineer at The Wolfson Unit, revisits the concept of motoryacht hull design, a topic he first explored in Issue 114, and questions whether hull design evolution over the last 40 years is making headway in reducing fuel consumption.

In recent years motoryacht designers have been very keen to offer designs that boast superior fuel consumption efficiency while underway. Since joining the Wolfson Unit as a consultant engineer in 2001, I have specialised in the model testing and performance prediction of high-performance motoryachts. When I say 'high performance', I don't mean just high speed; I'm also including efficiency or, more simply, the amount of fuel the boat needs to move forward at a steady speed.

There have undoubtedly been efficiency gains in the drivetrain, the engine, and shafting and propeller design, but what about the hull itself? I've been looking back through the Wolfson archives at the motoryachts we've towing-tank tested since 1970 to see if I can find evidence of improving efficiency. The Unit has towing-tank tested more than 420 hulls since then, with waterline lengths varying between 25m and 90m-plus from designers all over the world. Therefore, the data set should be reasonably representative of the evolution of motoryacht design.

There is one fundamental problem when it comes to measuring the efficiency of a hull shape: what assessment criteria can be applied? If you ask naval architects what affects the hull-powering requirements, they will probably tell you that 'it depends' – mainly on length, speed and displacement, with beam, draught and deadrise (for a planing-hull form) listed as secondary influences. At present, it's very difficult for owners to compare the hull efficiency of two alternative designs on what may be regarded as a 'fair basis'. Generally, comparisons of hull efficiency tend to be made on different yachts within a length range but this approach is too simplistic.

To illustrate the point, if we compare two displacement motoryachts of similar, but not identical, waterline lengths, both with identical displacements and travelling at the same speed, if one burns less fuel than the other (all things being equal in the drivetrain department) then it's more efficient, right? Well, yes and no. Strictly speaking, the boat that uses less fuel is more efficient, but the difference in waterline length will give the hull with the longer waterline an advantage as length pays when it comes to reducing fuel consumption at displacement speeds.

> The boat that uses less fuel is more efficient, but any difference in waterline length will give the hull with the longer waterline an advantage as length pays when it comes to reducing fuel consumption at displacement speeds.

Bearing all this in mind, the aim should be to produce comparative criteria by which these variables (length, displacement and speed) are taken into account and this will, in turn, allow a fair comparison of two differing designs.

In the 1990s the Wolfson Unit developed a comparison criteria that uses the effective power, waterline length, speed and displacement in the derivation of a performance number that the Wolfson Unit calls C Factor. This allows comparison of the powering efficiency of any two hull shapes at a given Froude number (Fr) which is proportional to the ratio of speed/ waterline length. The higher the C Factor, the more efficient the hull is. It is most helpful to think of Froude number as the mode the yacht is travelling in. At Fr of less than 0.2, the hull drag will be dominated by frictional drag with relatively little wave drag. A Fr of 0.5 is when wave drag is at its maximum and is commonly referred to as 'hull speed'. Frs in the range 0.5 to 0.9 represent the semi-displacement mode where the hull is climbing over its own bow wave, and greater than 1.0 indicates that the yacht is in planing mode where a significant proportion of the hull mass is supported by dynamic lift rather than just hydrostatic buoyancy.

Figure 1 shows the average C-Factor performance curves for monohull round bilge displacement (including semi-displacement) and hard-chine planing forms against Fr. The figures were derived from the mean of towing tank data from 152 hull forms. It's immediately obvious that, at low Frs, the displacement hull forms are very efficient, with the planing forms taking the lead at the higher Frs. We rarely test displacement hull forms at high Frs for obvious reasons, hence the lack of data for round-bilge motor yachts at this end of the scale, although the performance separation between the

> The choice of hull form comes down to whether the designer wants the vessel to be efficient at high or low speeds as this is where the difference in powering efficiency is most significant.

Figure 1

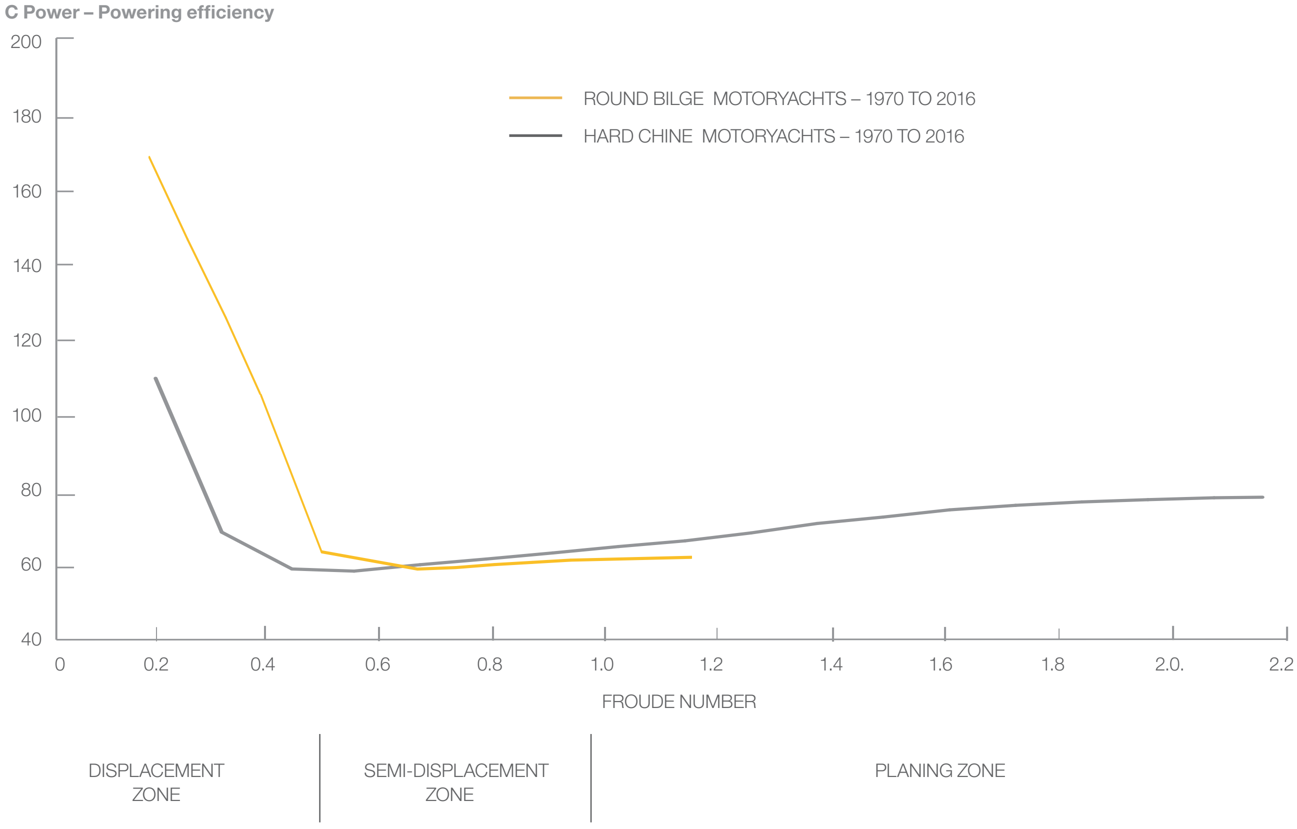
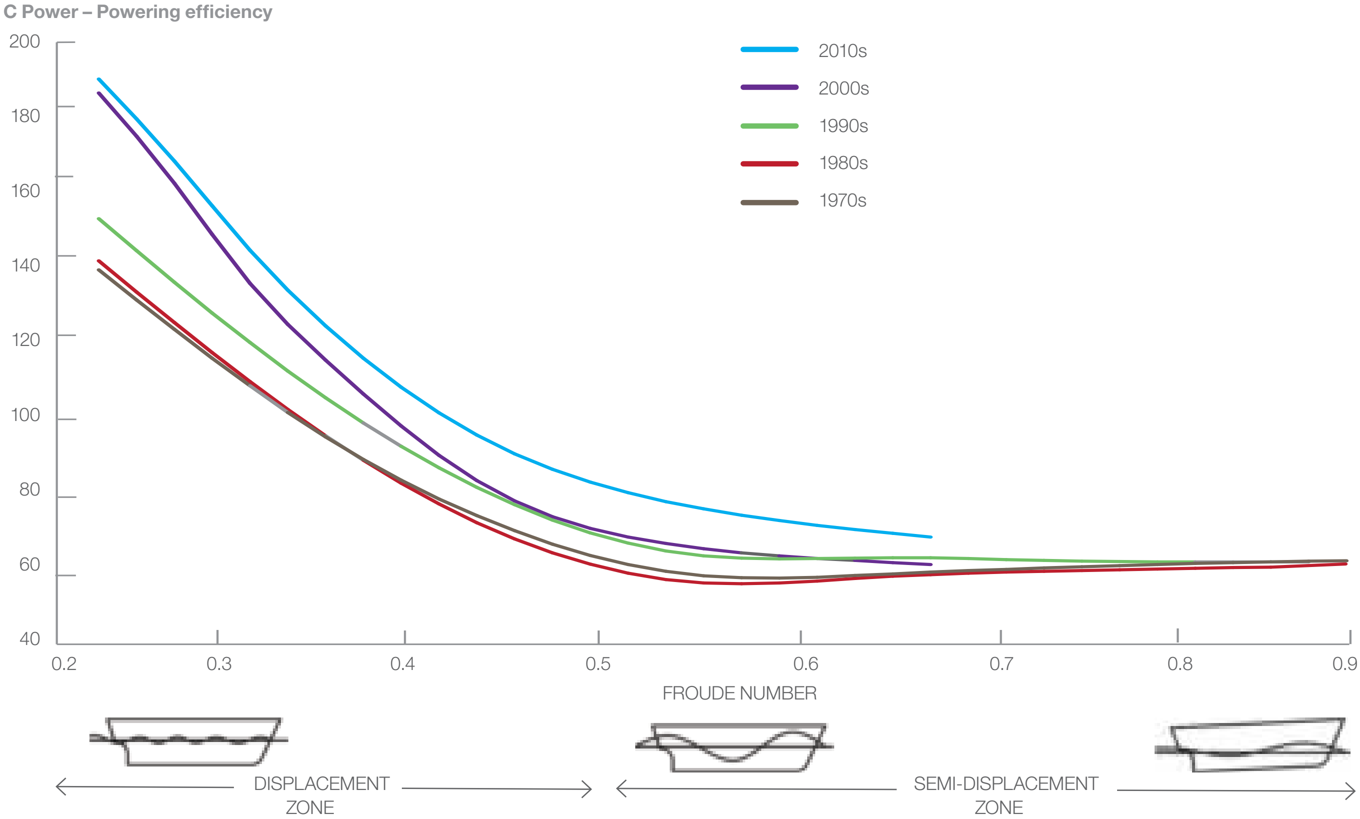


Figure 2



two types is expected to increase with increasing Fr. The powering efficiencies are very similar in the semi-displacement zone, so the choice of hull form comes down to whether the designer wants the vessel to be efficient at high or low speeds as this is where the difference in powering efficiency is most significant. The absolute advantage of displacement hull forms at Frs under 0.5 is clearly displayed in Figure 1. The reasons for the differences in efficiency between the two hull types are complex and far reaching, and are well outside the scope of this article. If you'd like to know more, read *Principles of Naval Architecture* – the essential reference book for naval architects! The benefit of the C-Factor approach is that it does make a very complex subject more digestible.

Generally speaking, there has been more evolution in displacement and semi-displacement hull design than hard chine over the past few decades. Planing-hull forms are essentially an approximation to a flat plate with warp/deadrise and relatively straight waterlines/buttocks, and, therefore, the scope for redistribution of buoyancy by changing the hull-surface curvature is relatively restricted. Bearing this in mind, and the fact that displacement hull forms represent a larger proportion of the large superyacht market, I've decided to focus on looking for design evolution in displacement and semi-displacement forms by plotting average C Factor against time – with the results displayed in Figure 2. Generally, the difference between the two hull types is that a displacement hull has round bilge sections and a semi-displacement has a more pronounced knuckle in the turn of bilge and a relatively flat underside in the afterbody sections.

The smaller 20-30m motoryachts are at a disadvantage compared to the longer superyachts as their L/B ratios can be much higher, and this also contributes to the differences in efficiency shown in the graph above.

The plot shows that average powering efficiency has improved with time since the 1980s, with the largest gains made in the displacement zone. Between the 1970s and mid-1990s, large motor yachts were typically 20m to 30m on the waterline as the era of the superyacht was in its infancy. As speed is seductive, owners typically wanted to achieve speeds of around 35 knots or more (Fr 1.11) and cruise at around 12 knots (Fr 0.38), where the boats were more fuel efficient. The knock-on effect of this was that in order to achieve 35 knots, the hull drag needed to be minimised at this end of the speed range and the natural choice was generally a hard chine planing form. This had a negative impact on efficiency in the displacement zone where a rounder bilge form would have been better. However, fuel was relatively cheap at that time and the fact that the yacht was using more fuel at cruising speed than was necessary was not a primary concern.

Then came the Millennium and the global boom that saw the growth of the superyacht industry, and with it yachts have become ever longer until the present day where waterline lengths of around 70m are not unusual, with a number of yachts exceeding 100m. During this period, with fuel prices rising and an increasing awareness of environmental considerations, the majority of owners were happy with top speeds of around 26 knots (Fr 0.3) and cruising speeds of around 18 knots (Fr 0.4), where absolute powering efficiency is significantly improved. As boats were then operating solely in the displacement zone, designers initially put some effort into minimising drag by controlling the afterbody rocker angle to reduce transom separation in the low Fr zone, which can be seen in Figure 2. Then the design community started more commonly to adopt bulbous bows, previously

> It's now typical for us to conduct a CFD study on a series of candidate designs with the one that shows most promise being taken on to tank testing for the most accurate prediction of absolute performance.

65M MOTORYACHT – VAN OOSSANEN NAVAL ARCHITECTS.

exploited in the commercial shipfield, which further improved efficiency at Fr beyond 0.4. Also, alternative trim-control devices such as interceptors were adopted to optimise running trim, offering an advantage over a transom wedge as they do not increase the transom area, and thus separated drag, at low Fr.

The length-to-beam ratio of a motor yacht has an influence on efficiency, and for displacement forms generally, the higher the ratio the more efficient the hull. However, there is a limit to how low the beam can be due to practical considerations such as stability requirements, fitting of the drivetrain and accommodation. This means that the smaller 20-30m motoryachts are at a disadvantage compared to the longer superyachts as their L/B ratios can be much higher, and this also contributes to the differences in efficiency shown in Figure 2.

In recent years, this relatively rapid evolution has been made possible by new tools that are available to the designer, the primary one being CFD. It's now typical for us to conduct a CFD study on a series of candidate designs with the one that shows most promise being taken on to tank testing for the most accurate prediction of absolute performance. From first-hand experience, we see that significant gains can be found using tank testing and numerical tools such as CFD to produce hull forms that consistently outperform the average C-Factor lines shown in Figures 1 and 2. We now provide our clients with a ranking number at incremental Fr to indicate how efficient their hull is compared to other contemporary hull forms, and this information is useful in indicating the cost of the design trade-offs that have been made against fuel efficiency.

The picture that has been formed during my investigation goes to show that, as ever, market forces tend to influence the trajectory of superyacht hull design. It is gratifying to see evidence that the design community as a whole is well positioned to respond to those influences and produce designs that are well matched, in efficiency terms, to the task at hand. ■

> We see that significant gains can be found using tank testing and numerical tools such as CFD to produce hull forms that consistently outperform the average C-Factor lines.

TO COMMENT ON THIS ARTICLE,
EMAIL: *ISSUE174@SUPERYACHTREPORT.COM*
WITH SUBJECT: ARE WE LEARNING ANYTHING?