The Plumb Stem – Fashion or Physics?

Conrad Cockburn CEng MRINA, GT Yachts Ltd. January 2013

Summary

The bow is the first thing that the sea experiences of your yacht. It is important that the bow and stem are designed properly so the sea can accept the bow with grace as we move through the water. This article discusses the effects of adopting a *plumb stem*, or vertical bow, in general terms.

Discussion

When we put to sea, it is important we know that our vessel has been subject to the right and proper rigour in design and engineering. In this regard, there are a number of fundamental aspects relating to hullform which are of paramount importance; this article discusses the advent of the plumb stem in sailing yacht design.

The plumb stem is nothing new however. Indeed the early *Dreadnought* type battle ships built at the turn of the century possessed something approximating a plumb stem. However, and this is a big *however*, these vessels were up around the 30-40,000 tonnes mark and motored at over 20 knots.

Recognising that sailing is largely a leisure pursuit, it is hardly surprising that the shape of the yacht is subject to variations in fashion. Whilst some trends in form can be accommodated with little impact on performance, others have considerable consequences. Bow form is one of the latter. The bow form is important because it is the first thing that the sea experiences of your yacht. How the sea and your bow meet and mate governs how your yacht responds in terms of pitching motion. Stern form is also important in this regard; however we will stick to the relative effects of bow form for the purposes of this article.

When designing our bow it is important to consider both the underlying physics of the apparent hydrodynamic situation *as well as* the current market expectations in terms of style. In other words, we must engineer the solution *à la mode*.

So, let's assume that the overriding requirement (in terms of fashion) is for a strictly plumb stem, which, some stylists would argue is true. What does this mean for actual performance? Let's start by looking at the cross-section shape where there are a couple of options with a plumb stem. In order

to include some reserve buoyancy (see definition box) it is necessary to increase the width of the cross section as we move higher above the waterline. However, if our stem is plumb then this will result in a corresponding increase in nose radius, see Figure 1 below. This is not ideal, however, because such bluff radii in the upper parts of the cross section will cause the yacht to suffer an increase in resistance in large waves due to the entry not being particularly fine. And as we all know, the key to low resistance is as fine an entry as possible. So in order to keep resistance to a minimum and ensure minimal speed loss in waves with a plumb stem, the cross section can be kept narrow all the way up to the deck, see Figure 2. This results in a form which will punch through waves since it has a minimal amount of reserve buoyancy to lift the yacht over the crest. There are two major effects of this - a very wet foredeck and very high pitching motion in certain circumstances. Why? With little or no reserve buoyancy to lift the bow as a wave passes, the vessel will tend to maintain trim, punch *through* the wave and the green water of the wave crest will simply spill on to the deck. The only way of compensating for this is to locally increase the height of the bow. Damen Shipyards and Delft University have done this in the form of the Axe-Bow, but notice the massive freeboard (large windage) in the forward part of the vessel and the accommodation located far aft. These are necessary compromises due to the lack of width in the forward part of the hull.

Reserve Buoyancy
As the width of a cross section increases with height, the effect is to increase the amount of buoyancy rapidly by increasing the buoyant volume as the yacht pitches bow-down. This attribute of the hullform is called reserve buoyancy and acts against excessive pitching. In energy terms, there is an increase in waterplane inertia to quickly counteract the kinetic energy in the pitch motion.

In extreme circumstances the cross section widths increase substantially resulting in a distinctive *flare* in the very forward most part of the hull which can result in slamming.

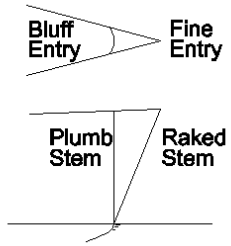
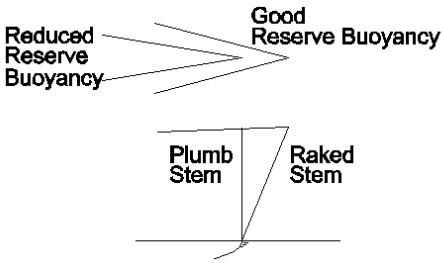


Figure 1 - Preservation of Reserve Buoyancy at the Cost of Hull Resistance



Figurre 2 - Preservation of Fine Entry at the Cost of Reserve Buoyancy

OK so what? A plumb stem gives us a nice fine entry all the way up so we don't increase the resistance in waves and we add nice high prow

This is not an ideal performance cruising yacht

to avoid taking green seas over the deck. How about at anchor or at very slow speeds, the kind of speed that a sailing yacht would sail at most of the time? Well, without the reserve buoyancy in the bow, the vessel will pitch violently in certain seas. This motion can be very bad at anchor, just when you're settling down with your gin. Instead of a slow wallow to rock you to sleep, the yacht can experience large pitching and keep you awake. Not the desired result at all. Reserve buoyancy designed into the hull form prevents the vessel from pitching in this way.

The other reason for a plumb stem is to maximise waterline length, which for an equivalent vessel displacement will result in a reduction in resistance. However, this is cheap speed and must not be implemented at the cost of seaworthiness. A naval architect must ensure drag is kept to minimum throughout the form whilst preserving a hull with good seakeeping qualities.

At GT Yachts all these factors are considered because we apply fundamental rules of naval architecture while also seeking to accommodate the latest styling features. Our stem rake is such that it can develop enough reserve buoyancy but preserving good waterline length for speed while looking good too!