The second half of Graham Taylor’s two-part exploration into recent developments that could shape fast boat designs of the 21st Century.

In Part One we explored how to go faster through the water with the latest wave piercing technology. We also began to consider how steps in the hull could improve performance across the water. In this final part we will conclude our examination of steps, and look at aerodynamics to see what happens above the water is due for a change.

Step This Way:

Probably what puts most people off experimenting with stepped hulls is the hit-and-miss nature of their stability. Undoubtedly the greatest problem associated with stepped hulls is the ‘porpoising’ I mentioned in part one. Crossing a wave is a bit like driving over a speed bump on a motorbike, with the front and back pitching up and down. A strangely similar pitching effect can occur at high speed on smooth water. The craft starts to nod, then skip alternately on its front and rear planing surfaces. This action can become increasingly violent, with the boat making its own waves! To solve this problem the layout of the stepped hull is critical. In my experiments I’ve yet to find a golden rule that determines what will work and what won’t. One model had no real vices, another porpoised only in calmest of water while the third was positively dangerous!

Should the step have a more or less vee than the transom? Should it have a greater angle of attack? What is the best shape for the step? And where should the centre of gravity be - should the boat ride mostly on the

The incredible lines of Ocke Mannerfelt’s B28 ‘bat boat’ that take aerodynamics to a new dimension (photo courtesy Ocke Mannerfelt)
A fitting conclusion to this series, the B2N demonstrates its fine bow, its aerodynamic shape and its narrow stepped hull. (photo courtesy Ocke Mannerfelt)

Shape of Things To Come

Part 2

step or the transom? What about the thrust line, inertia and natural frequency? All these factors interact to create stability or instability. It can be quite alarming to find your model leaping from nose to tail like a demented dolphin in the middle of a high speed run!

There are different schools of thought on all the above issues. I've heard one rule of thumb used by 3-Pointer racers that places the centre of gravity at 17% of the distance between the step and transom. What about the shape of the step itself? Should it just cut straight across the hull or should it come to a point like on some flying boats? The trouble with the straight and pointed steps is that they result in the boat riding on a very narrow area of the hull with virtually no stability against roll or propeller torque (as I found on one of my models).

Breaking Step.

Back in the 50's two highly regarded engineers, Eugene Clement and John Plumb, came up with an alternative step layout which they called the 'Dynaplane', aimed at overcoming the stability problems. They showed that a swept back step creates a short wide 'footprint' which gives better roll stability and is more efficient than a long narrow one (see Figure 2). Also they proposed that the front step should carry 90% of the craft weight while the boat would be stabilised by an adjustable rear planing surface. This idea was developed by BP into the Pacesetter, an experimental gas turbine powered Class 1 offshore powerboat of 1980. Pacesetter featured a step which was swept back at 60 degrees while it rode on hydrofoil stabilisers at the rear. Sadly, due mostly
The wide delta-winged shape of the Ocke Mannerfelt B28 hull form is evident in this view.

To non-technical reasons the project was abandoned, but not before Pacesetter had attained 87 mph in tests to prove her concept.

You might have expected the story of the stepped hull to end there, but a couple of years ago powerboat designer Lorne Campbell revisited the Dyna-plane concept to design the Shakespeare 960 Sportsracer. Unlike many early stepped boats which had more vee and angle of attack on their front planing surface than their rear, the Sportsracer cunningly achieves stability through having its transom the deeper and steeper of the two.

**Stepped Hull Models.**

What makes stepped hulls a particularly attractive model subject is their forward centre of gravity. This allows plenty of room for engine and conventional prop-shaft drive train.

For those scale modellers with high speed yearnings the CMB’s are excellent model subjects. Indeed I remember seeing a CMB kit on the market. Similarly the Italian MAS 500 series and Soviet G5 torpedo boats would make exciting models for the scratch builder. Those of us with more of a penchant for power will find that stepped hulls offer a robust intermediate model between monohull and 3-pointer performance. One or two strategically placed steps could transform a soggy model into something a bit more zippy.

A final point is that it is important to allow a free flow of air behind the step, or a suction will occur that sticks the boat down and puts the brakes on.

**Stepping up the pace.**

Although hull steps date back to the turn of this century their story of development may just be beginning. There is no doubt that correctly designed steps can cut down drag and dramatically increase speed. We can expect to see more of them in both full size and model mono and catamaran craft of the future.

*The swept back Dyna-plane step of Lorne Campbell’s test model for his Shakespeare 960 design. (Photo courtesy Lorne Campbell)*
Flying in the Face of Reason.

Now we are ready to grapple with the future aerodynamic qualities of boats. As speed increases this is something that deserves greater consideration than it has been given in the past.

What is the difference between an aeroplane and a boat? "One floats and the other doesn't?" you might reply, or perhaps "One takes off and the other doesn't"? - far from the truth! No, the answer for the purposes of this section is "The aerodynamic configuration".

To demonstrate what I mean take your model powerboat, hold it level at arms length and let it fall to the ground. Now take your mate's model aeroplane and do the same. Although this might seem like a recipe for a big repair bill and a trip to hospital, the chances are that the boat hit the ground tail first whereas the aeroplane struck nose first. I use this to illustrate how, for aerodynamic stability, an aeroplane has its centre of gravity ahead of its aerodynamic centre, yet a boat's hydrodynamic need for rearward centre of gravity too often places it behind the aerodynamic centre and makes it unstable according to the principles of flight.

Part of the popularity of the current layout is to ensure that if a boat takes to the air it lands stern first, since bow first landings can result in it playing submarines and chasing the fishes. However, one cannot help thinking that we have yet to get the aerodynamics right, because fast boats should be considered as flying machines. As I suggested earlier, planing lift cannot reduce the wetted area of a non-stepped hull to a point much behind its centre of gravity. So when our models whistle by with only the prop in the water, they are balancing aerodynamic lift and drag against the propeller thrust.

The State of the Art.

Aerodynamic lift is an attractive way to reduce the amount of boat that is dragging through the water. It is created under the bows, in the tunnel if there is one, and to some extent over the deck. The next effect of this lift is normally nearer the bow than the stern. The last thirty years have seen considerable development in the use of aerodynamic lift. During this time, the once controversial catamarans have come to claim supremacy over the monohulls in circuit and offshore racing. But they are far from perfect and fly by the seat of their pants.

In order to generate aerodynamic lift, modern catamaran craft have to be run at optimal angles of attack, most often obtained through a rearward centre of gravity and use of power trim. Also, the craft's natural angle of attack will vary according to its airspeed. In practice this means manual adjustment of the trim to balance the craft in an attitude somewhere between low angles (which create little lift) and high angles (which create high drag and threaten blow-over). Some inherent stability is achieved through the opening and closing of 'the slot' (the gap between the spars and the water surface) which opens to release excess air pressure as the angle of attack increases, and sometimes results in a nodding behaviour. Wave or gust impact can vary this attitude in an unpredictable fashion. Stability is further complicated by the way the net effect of aerodynamic lift (centre of pressure) tends to move about, depending on the angle of attack and, in the case of catamarans, the height of the wing-shaped tunnel from the surface. I could find little data on this but theory suggests it moves forward as a catamaran increases its incidence, from around 1/2 cord to 1/4 cord length, causing perhaps a 50% increase in lift moment (leverage) about the transom. No wonder cats are so sensitive to trim changes. Finally, a tunnel is capable of sucking as well as lifting, and if the tunnel's leading edge ever gets submerged it will be swiftly followed by the rest of...
The Pacesetter’s stepped underside, with hydrofoils which lift and stabilise the back of the boat. (photo courtesy BP Photographic Unit)

The ‘hydro’ end of a Russian designed ‘hydrowat’ The conventional catamaran sponsors end about 8m from the stern but the tunnel continues to form a ‘hydroplane’ air cushion.

The Leading Edge.

Some interesting features have appeared to try to counter the faults of the catamaran. One of the leading innovators of full size boats is Fabio Buzzi, whose offshore racing catamarans, such as the awesome 1882 CESA, have a sprung control flap part way down the tunnel to release excess pressure. Another feature seen on many modern cats is a transom flap (see Diagram 2) to adjust the ride height at the stern, as found on the latest Miller Agnew/Lorne Campbell model. The idea dates back to the elevator control on ‘Switzer wing’ cat’s of the 1960’s. While lifting the stern the flap also has the less desirable effect of pitching the nose down.

A more recent development in the circuit racing field is the ‘hydrorat’ which, as its name suggests, is a blend of catamaran and hydroplane. It has a catamaran front end, but at the rear the tunnel is extended to give a large hydroplane-like air cushion ‘footprint’ which spreads the weight of its outboard engine (see Diagram 3).

Coming back to our original problem of having the aerodynamic lift at the front and the weight at the back, perhaps a deltawing shaped is a logical solution, since this puts lift and centre of gravity closer together. There have been some exciting developments in this field, with radical new delta-shaped monohulls appearing in circuit and offshore racing. Any resemblance between the shape of Ocke Mannerfelt’s B28 ‘bat boat’ (see photos) and the craft from NASA’s ‘lifting body’ programme of the 1960’s (remember the opening sequence of The Six Million Dollar Man?) may seem purely coincidental, but similar thinking is behind both. The whole B28 is a lifting, aerodynamic shape. Its smooth lines are also claimed to help it go 24% faster than a conventional monohull of the same power.

Mach One?

Looking back at the developments over the years and trying to project forward one can’t help noticing certain pitfalls in current thinking. Expect big changes in 21st Century. In this article it has only been possible to scratch the surface of the subject. Although speeds of up to 100 mph may seem fast to us model boaters, we are still in the relatively un-researched realms of low speed aerodynamics that haven’t progressed much since the days of the biplanes. We’d have more data if we were going for Mach One. Paradoxically, our models speeds are also equivalent to full size speeds of several hundred miles an hour, which just goes to show that we should take aerodynamics more seriously.

The Future Today:

I hope that you have enjoyed this tour of powerboat ideas that will shape our craft in the next century. Wave-piercing hulls, use of steps and aerodynamics will feature highly in the craft of tomorrow. Very few people have seriously explored these areas, and even fewer have written their findings down or divulged them to the outside world. It means there are no magic formulae to guide us in our hobby, so it’s trial and error for all of us!