There's no better illustration of the nuanced benefits of a change in the transom immersion and aft run than the use in some of the 2008-generation Imoca designs of adjustable aft flow control. This is the 2008 Farr design *Virbac* of Jean-Pierre Dick which featured a two-segment split transom flap system which could be raised or lowered from the cockpit. This allowed a little more rocker than would otherwise be desirable for high-speed sailing so better light and medium-air performance with the flaps raised

JEAN-PIERRE DICK

Old dog new tricks

In these strange times, held in the grip of the coriander virus, once you've tidied your sock drawer for the third time and seen all your favourite movies twice, we do still have some time to reflect on how we got to where we are. The development of the ORC VPP might not be everyone's first port of call for rumination, but it is an interesting case study of how the field of Artificial Intelligence (AI) has infiltrated our lives.

When you look at it with the benefit of hindsight we can recognise now that at its outset the IMS VPP-based handicap was a hubristic step into the unknown. The belief that you could reliably predict the performance of a fleet of random boats using a very simple parametric description of their hull and their sailplan was bold indeed. The aim was surely altruistic: to escape the type forming of the rating rules in place back then and establish a new rule where you could race any type of boat on a level playing field.

For the ORC today the goal is still the same: we try to produce handicap polars that reflect the performance of any boat based on the measured dimensions of the hull and the sailplan. To do this we need to create force models based on the dimensions and calculated quantities of weight, sail area, keel area and so on. Some of these are easy: having bigger sails, a taller rig and more stability all make a boat sail faster. But the nuances of hull resistance and sail forces are much more tricky.

When IMS started in the mid-1980s a lot of engineering calculations were still done using a slide rule, and the early desktop computers like the Commodore PET. Computing power of course is now many orders of magnitude greater than back then… ask a modern engineer about log tables and he will direct you to the nearest IKEA.

The VPP started off using tank test results taken from 20 or so models and a crude representation of rig performance. It was a very capable VPP, sensitive to changes in displacement, length, sail area, rig height and draft. To design a boat, it was a perfect tool. Remember how those first-generation IMS boats were much faster and easier to sail than their IOR cousins of the same size?

However, if you wanted to handicap a racing boat designed to exploit this early VPP, it was less than robust. Over time it became way too easy to design a boat that had a lot of slow features but sailed faster than the VPP thought it should. These rule beaters, along with complex scoring, gave IMS a bad reputation outside some small well-funded groups in the Med who were thriving on new rule exploitations. The International Measurement System had morphed into the Italian Measurement System (although truth be told there were plenty of Spanish teams doing the same).

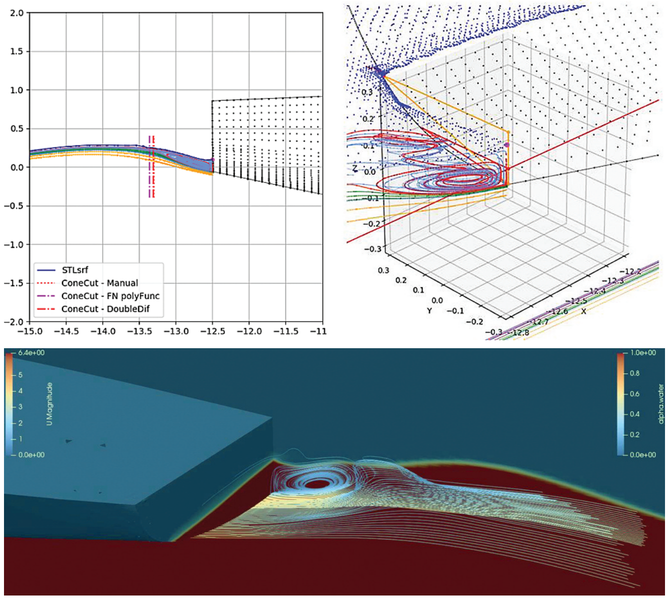
At ORC we have been working to widen the appeal of our product for grand prix racers and club sailors alike, and slowly the system has improved and the fleets are growing. One of the tools being used to enable this improvement is AI.

With ready access to better and faster computers, for hydro modelling we have gone from having only 20 hull types to cover all the boat types in the world, to being able to run 1,000 hulls in Computational Fluid Dynamics (CFD) computer codes. On the aero side we have gone from having a handful of wind tunnel tests to being able to run several thousand 'virtual wind tunnel' simulations. And to analyse all this data we have moved to an M & S (Modelling & Simulation not Marks & Spencer) approach. And to make sense of all this data we have had to adopt AI.

What this means is that we have a huge data set of cause and effect from which to derive some sensible conclusions. For example, we now have 3,000 wind tunnel tests with different wind angles, sail trims and traveller positions. Some of these are 'good' tests, and a lot of them are 'bad' tests in terms of making the boat sail fast. But that doesn't matter, because in the AI process the machine needs to learn what is fast and what is slow, and it can't do that just by having all the runs being close to perfection. In fact, what we are trying to do is to take all sorts of sail trims and identify what's fast.

To do this we take our 3,000 CFD results, each one characterised by a set of variables, say, 10 things: main camber, jib camber, boom position, jib lead position fore and aft, and position in and out, jib twist, main twist, mast height, overlap and fractionality. This is our 'training set', and the computer then 'learns' from all the interactions between these trimming and shape parameters so that the performance of the sailplan, trimmed in the best way, can be calculated ▷

JAMES BOYD



***Above*: the transom flap alternative favoured by designers Owen-Clarke was the Interceptor – employed on their Imoca designs for Mike Golding's *Ecover* (*here*) and Dee Caffari's *Aviva*. The Interceptor is a vertical carbon blade running the full width at the bottom of the transom that is raised or lowered into a narrow slot. Designed originally for Russian high-speed naval vessels, when it is lowered it locks in a wedge of water acting as a virtual trim tab. This is *Ecover* sailing at speed with the blade raised (*top*) showing displacement sailing flow off the stern and with the blade lowered and stern lifted (*above left*) with a clean wake more like a planing dinghy. Golding found an upper speed limit cut-off at around 17kt, at which point he needed to lift the bow again to go any faster – and maintain control. *Right*: examples of the numeric calculation and CFD modelling employed in the course of the ORC's new research into transom effects**

based on its definition in terms of these chosen parameters.

Choosing the parameters is the key element to this AI process. In understanding the aero factors the training set parameters need to be influential on sail performance. To illustrate with an analogy, imagine that we are using this approach to make a perfect-tasting pancake: we can see how the ratio of eggs to flour to water and the pan temperature and cooking time are likely to affect the taste, and if we made 1,000 random pancakes we should identify the best pancake recipe. If, however, we decided that the important parameters were the colour of the mixing bowl, or whether or not we use an electric mixer we wouldn't learn much. And so it is with 'parametric' force models: if you don't characterise your training set with sensible parameters no amount of AI can rescue you.

Using this approach we now have an improved aero model, and that helps not only because we can predict effects like heeling force and thrust more accurately, but also how this affects other forces. For example, one of the vexing questions we have had since adoption of this method has been why does the VPP tend to overestimate the benefit of stability? There's no question that having more righting moment helps performance, why else would people hike? Yet depowering is also beneficial: as the wind strengthens to keep a boat on its feet you have to depower the sails, reduce the heeling force, and get the centre of effort lower.

Aerodynamic theory and wind tunnel tests both show that as you depower with increased windspeed the overall sailplan efficiency is reduced because the effective span is reduced. Therefore a stiff boat enters this zone of reduced efficiency less quickly as the wind rises. Turns out that we have been over-estimating this loss of efficiency a little bit: our AI analysis of the virtual wind tunnel data showed that there are sail trimming strategies that can mitigate the loss of efficiency that our limited wind tunnel test database couldn't identify. When that was introduced into the VPP the bias towards favouring stability was reduced.

Now we have moved our force model a step closer to reality and the predictions all work better. Talking of reality, it is entirely possible that the top sail trimmers have reached the same conclusion as the AI thanks to their years of trimming experience and feedback from skilled helmsmen – it's come full circle. This just goes to show that a degree in engineering is not required when trimming sails.

On the hydrodynamic side we are engaged in a magnum opus, a world that is not as comfortable as easily defined sail shapes and an airflow that is undisturbed by the water. Now to be accurate the VPP must also deal with hull drag which is in two parts: the hull friction, which for now is under control because there is a wealth of published data about which coefficients to use and, knowing the wetted surface area and the boat speed, it's an easy calculation.

The other component, however, is wave-making (or residuary resistance, so called because it's the bit left over after you have taken away the friction resistance) – and this is more problematic. It depends not only on how heavy the boat is but also how long and wide it is, how the hull volume is distributed towards the ends of the boat, and crucially how much transom area is immersed in the hull wave system… this is a distinct feature on most modern fast designs.

There is no doubt that moving from 20 tank tests analysed with a slide rule to 1,000 tests processed with a modern computer's neural network has made a big improvement. And this means it's no longer as easy for the yacht designer to look at the rule and decide which parameters he can exploit for a favourable handicap.

But as hull shapes have moved towards shorter aft overhangs this 'transom drag' is a factor that must be tackled. What's needed is a characteristic 'wave-making length' that is sensitive to where the aft end of the boat is *and* a method to capture the drag of the recirculating flow behind the transom.

In the course of 300 CFD runs, undertaken by Jason Ker and his associate Marcus Mauleverer, the position of the running waterline along the hull was captured and analysed to build an algorithm that can predict this running waterline position around any hull. This in turn means that the position of the waterline at the transom can be determined. Also the wave pattern aft of the transom can be calculated and used to define an aft end of the effective waterline.

Knowing the wave pattern and the immersed depth of the transom, another algorithm was devised to predict how the water behind the transom behaves. For a boat with an immersed transom at low speeds the water recirculates behind the transom, but as speed increases the wetted transom area reduces and finally at top speeds the transom runs clean. Given this effect it's crucial to calculate the extent of transom wetting and the associated pressures on the transom – because when it is wet the water is 'leaning' on it and thus pushing the boat forwards.

Said quickly this all sounds do-able, but spare a thought for the poor engineer who sits bleeding from the ears to try to make this work. We're fortunate to have such dedicated experts on our ORC team, and this pause in racing for a few months may very well help us get more out of them this year on VPP progress than in otherwise frantic times.

Andy Claughton, International Technical Committee ❑