WOLFSON UNIT
FOR MARINE TECHNOLOGY &
INDUSTRIAL AERODYNAMICS

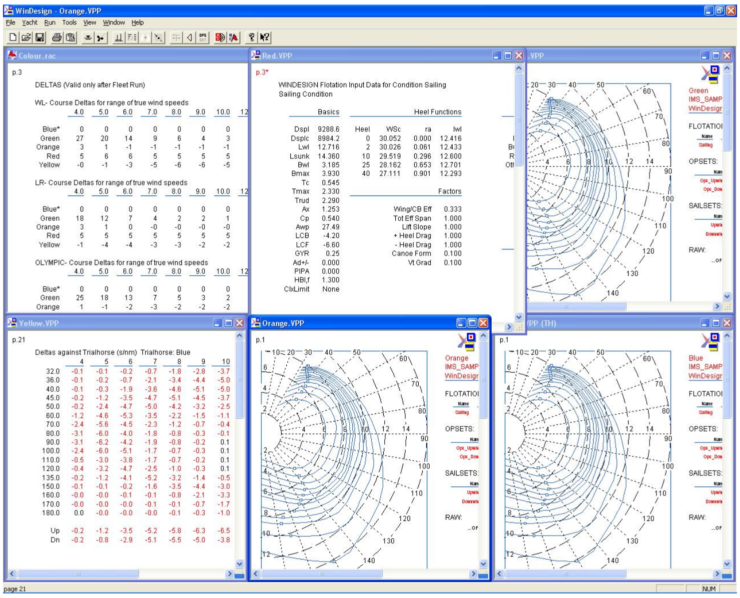
As the Battle Rages….
(or VPPs, what are they and what are they good for?)

The Wolfson Unit at the University of Southampton test yachts in towing tanks and wind tunnels, as well as writing programs to predict performance. John Robinson describes the pros and cons of the VPP, and how to make best use of it.

1.1 Seahorse International Sailing Magazine, Article p37-p39 Issue 306, August 2005

Sailing is about forces, balancing forces in fact. Just watch a windsurfer or a foil borne Moth and it becomes obvious. The active control of sails, foils and weight are there for all to see, acting in real time. We also enjoy our sport on the interface of two fluids, indeed it is only the presence of that interface that allows us to sail at all. So if you want to make some kind of an analysis of the physics of sailing it will be about balancing forces that are generated in the air and water. That is where a Velocity Prediction Program (VPP) does its work.

VPPs, like most new tools, are simply a modern approach to an old problem. Physics doesn't change, so if you wanted to set a handicap, or find a flaw in one, design a boat for best speed, or resolve the results of a tank test, you had to take account of the force balance calculations somehow or other. Where the modern Vpp really scores is that it contains so much of the information needed to do this, and takes away all the time involved in the maths, producing a neat set of polar speed predictions covering the requested set of wind speeds. In addition, a good VPP will allow the user to compare multiple sailing conditions, and multiple boats, around a race course, and point the way to design optimisation.

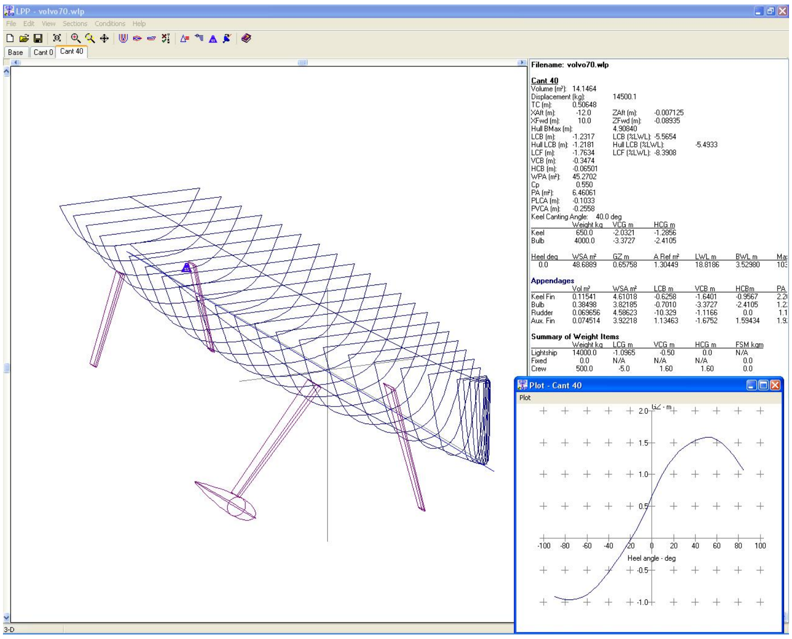


The key to success lies in understanding the limitations of the data you are working with, and the methods of calculation used. Let's start with the data.

Fundamentally the VPP has to be able to estimate the aerodynamic and hydrodynamic forces that are generated by a sailing boat over a range of wind strengths and at true wind angles from hard on the wind to a dead run. It does it with a mixture of theoretical analysis and empirical data. There are forces from the rig that drive you forward and sideways, and heel the boat too. There are forces from the hull and foils that resist forward motion, stop you sliding to leeward, and resist heel.

University of Southampton

Resistance to heeling, stability, is usually calculated by an associated theoretical analysis program called the Lines Processor, or LPP, which, given the hull form and centre of gravity can determine the shape of the stability (GZ) curve. In addition it provides the VPP with data such as wetted area, hull length, and other parameters that will allow the VPP to estimate resistance and sideforce characteristics. These are usually pretty precise measures. The VPP can use the stability data directly, but as for the other information, it has to use that to estimate resistance, and the ability to generate sideforce. Where does it get that data form?



If you are lucky, and have spent a bit of money in the process, you may have the results of a tank test on your particular hull. There is no doubt that at present this is the method that will get you the most accurate prediction of resistance. In this case all the VPP has to do is to look up the data in the matrix of test information, and use it directly in its calculations. However, if there are no test results available, another method has to be used, and this relies on empirical data averaged over a wide range of hull forms that have been tested in the towing tank over many years, such as the Delft University Series.

Now we are moving into areas of less certainty. A good statistical analysis of a series of hull tests on varied forms will claim to be within 5% of the correct values in 90% of cases, and that assumes that your hull type lies within the envelope of forms in the tests. Furthermore, such published analyses of necessity lag behind design trends, so be realistic in your expectations. There are few better tools around than the VPPs we have, but don't expect them to be able to predict everything to the last percent. Here we can become fortunate though, because even if the absolute values we predict are a bit out, the relative differences between two versions of the same design, or similar hull types, are much smaller, and this is really what the VPP excels at, pointing to improvement.

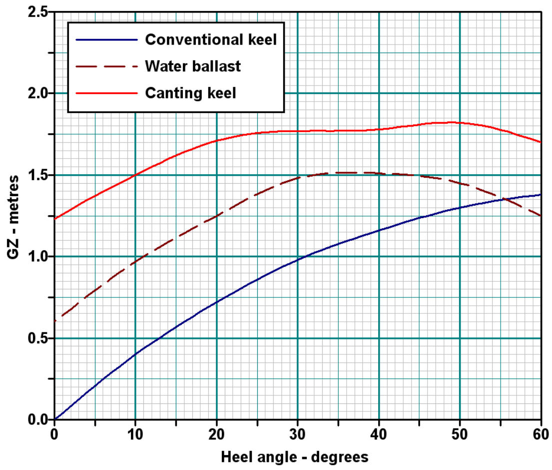
Similar comments hold for the aerodynamics of the rig. If you have Wind Tunnel results, or some good computational fluid dynamics (CFD) you can plug this in and the program can use it to look up the data. Note that CFD data on sails tends to be closer to the truth because the flow is a better understood, and easier to calculate, phenomenon than the hydrodynamics of a craft at the water surface, principally due to wave making. As before, if you don't have real data the program will have to calculate it for you on the basis of a few numbers, like I, J, P, E etc. Once again we are into predicting from averaged data over many different sail plans, sail aspect ratios, mast and rigging specifications and more, so absolute precision decreases.

So knowing the basis of the data we enter into the program can inform us about how to use it. If you are looking to compare hull characteristics, it's probably a good idea to try and keep the rigs the same, or vice versa if you want to see what sail plan changes do. Like any scientific experiment, try and keep it down to changing one variable with all the others constant if you want to have a chance of understanding why the thing is giving you the answers it does.

What then does the VPP do with this data? As I said at the beginning, it's a matter of finding a balance. At every wind speed, and every true wind angle there should be a point where all the forces do balance, those are the points the program it trying to find, and when it does it will tell you what speed the boat is doing, what angle it is heeling to, and perhaps which sail set it has chosen to use. It can give you a lot more information as well of course, but ultimately it's the speed that we are really trying to get at.

The way it works is by solving a large set of simultaneous equations for each chosen wind speed and angle. The more variables it tries to manipulate the harder the task it sets itself. It's an iterative process. It goes round and round, fixing variables one at a time until it finds a unique solution point. Of course it is possible that there may be more than one solution, especially if we are asking too many questions. A VPP that tries too much in the way of altering sheet leads, sail camber or rudder balance is stacking up problems for itself. Just coming to a solution for optimised aero and hydrodynamics is hard enough.

The same is true if we are comparing a whole sail wardrobe over the full range of wind speeds, all at the same time. It just doesn't make sense to ask the same questions about your lightweight genoa as your trysail. You use them in different winds in practice, so should the VPP.



An interesting example of this comes when using a VPP to work on canting keels. The graph shows three stability curves, a conventional yacht without moveable ballast, a water ballasted hull, and one with a canting keel. Moveable ballast boats have curves that flatten out at lower heel angles than conventionally ballasted ones, and this presents a difficulty for the programs, because heel angle is one of the key variables that is changed within the iterative calculation. The slope of the curve is another key value, used in assessing where it's next best guess at a result will lie. Practically speaking however, you never want to sail a canted keel at angles much more than 15 – 20 degrees, apart from anything else the bulb is getting close to the surface and causing more wave drag. But the VPP may not know this implicitly; indeed it may be trying to let you use it for anything from a Sail Training Ship to a Mini Transat. So you need to give it a hand by limiting its search area to realistic sailing angles.

Once you get a reliable set of speeds however, the interesting bit can begin. You can extend the program by comparing the same boat with different sail settings. You can design a series of hulls with logically varying hull parameters, and see how the results trend. Determine how hard it is worth getting the crew to hike out, or sail a fleet of designs around the buoys, or even round the world with statistically varying wind patterns and see which is likely to win. This is what a VPP is really good for, in fact there aren't many other tools you can use for these, except the real thing of course.

Designers can use them for design comparison and optimisation. Rule makers can create new classes, the ACC was originally designed around one, and VPPs were first developed as part of the project that lead to IMS, which is wholly VPP based. What's sauce for the goose is sauce for the gander of course, designers then use VPPs to find the holes in rules.

Owners and teams use VPPs for developing tactics on the racecourse and specific venue, think how hard the AC syndicates are looking at wind patterns in Valencia right now. You can use a VPP to develop a protocol for sail selection based upon wind speed and heading, or simply to set target speeds for the crew to work to.

So the VPP is a versatile and necessary tool in many areas of sailing. It has its limits, it won't design your boat, or predict with 100% accuracy whether you will win, to say nothing of crew skill. It may not be a universal panacea, they don't exist of course, but whatever you try and use in their place will still be a VPP.

Let's sum up with a few rules of thumb for getting the best out of your VPP. Know your data source, and use this knowledge to set your levels of expectation about the final precision of the results. Remember that relative differences can be much more accurately defined than absolute results. Keep it as simple as you can, if you confuse the program with a host of options in one run don't be surprised if it is hard to see the trends. Don't ask the program to decide on impossible situations, you just aren't going to sail with you code zero in 35 knots of wind, even if the sail makers could find a material strong enough. Don't expect miracles, magic and physics are mutually incompatible.