Background Article

Applying the velocity prediction program in design

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Although the sophisticated CAE (computer-aided engineering) methods are excellent for determining parameters like deflection, drag or lift, they do not directly tell the designer much about the performance of the boat. For the complex task of trading-off performance parameters against each other, the designer turns to the velocity prediction program (VPP).

The VPP

Velocity prediction programs are typical of a class of methods often referred to as engineering methods. Textbook methods typically taught at university level are mostly direct applications of fundamental theory, and have to be modified a bit to deal with the real world. Numerical methods like FEA (finite element analysis) or CFD (computer fluid dynamics) can simulate the real world quite accurately, but only with highly trained and experienced users, as well as formidable computing equipment. By contrast, engineering methods are typically based on textbook theory, adjusted with a large amount of empirically derived data, such as wind-tunnel and tow-tank tests. Historically these empirical corrections were published in the form of charts and tables, but in today's world the information is readily available in a reasonably user-friendly computer program, almost universally referred to as a VPP.

Several organizations such as research institutions, sailmakers and even individual America's Cup teams have developed VPP's. Team Shosholoza is using WinDesign, sold by the Wolfson unit of Southampton University. From a designer's point of view, the principle characteristic of a VPP is that it provides almost instantaneous answers, as opposed to CAE methods, which can take minutes, hours or even days. In addition, because the VPP has been extensively calibrated against experimental data, its predictions can be expected to be accurate and consistent, as long as it is used within the limits that it has been calibrated for.

Using the VPP

A VPP does exactly what its name implies. Starting from input parameters that characterize the performance of a yacht, the program calculates the speed of the boat at the relevant points of sail. The typical output from a VPP is the well-known performance polar, which contains the predicted speed of the boat at different true wind speeds and angles. The designer

can use the VPP to quickly determine the performance implication of a change to the design. As a simple example, consider the implication of making the boat wider. A wider boat generates more righting moment when heeled, and can thus carry more sail force, but it will also usually have more drag, particularly when sailing downwind, and will likely be slower than a narrow one on this point of sailing. When sailing upwind, the extra sail carrying power will make up for the additional drag (up to a point), and the wider boat may be slightly faster.

It is clear then that the designer has to balance these contradictory factors very carefully to find the best combination. The VPP allows the designer to quantify the effects of these changes quickly and systematically. It is interesting to consider that even this ostensibly simple trade-off is more complex than it sounds, as can be seen most graphically when comparing the wide 1992-era America's Cup boats to the more developed skinny ones of the late 1990's and today.

Surprisingly, the absolute speed prediction accuracy of the VPP is not that important. It is mostly used to compare two very similar designs that differ only in small details. It is thus most important that the VPP is able to estimate the effects of small changes correctly. A good VPP can predict the effect of even small variations in the main parameters quite accurately.

Some of the main parameters are simple ones such as length, stability, mast height, keel depth, etc. However, many other design parameters such as the choice of keel cross-section and the detail of the hull shape are dependent on complex hydro- and aerodynamics, and as such are not well modeled in the relatively simplistic VPP. To quantify the effect of changes to these characteristics it is necessary to update the VPP with more detailed inputs obtained by numerical or experimental methods. A suitably updated VPP thus becomes an extremely versatile and powerful design tool.

The VPP can also be used to good effect to identify the design parameters that require most attention. It might show, for example, that a particularly aggressive, time-consuming and expensive weight saving campaign might save only 2 or 3 seconds around the course, but that 10 or 12 seconds could be gained from a good bulb optimization study. In a perfect world where resources are unlimited, one would pursue even the smallest gains, but in reality one has to focus resources on the bigger gains first.

Conclusion

Although many very expensive and high-tech design aids are used in the design of an America's Cup yacht, the velocity prediction program is the tool that is used to combine the inputs from all these methods, so that well-balanced design decisions can be made.

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