New approach to VPP

Kevin Cudby discusses his part in Jérémie Raymond's PhD project on the study of potential design tools for the keelboats of the future. The project focuses on planing phenomena, an important topic for Groupe Finot, who financed the project.

Raymond's systematic hull series was based on recent Open 60 hulls from Groupe Finot, such as Yann Elies's *Generali*, photographed off Port-la-Forêt, France in October 2008 (Credit: Jean-Marie Liot/DPPI, courtesy Vendée Globe).

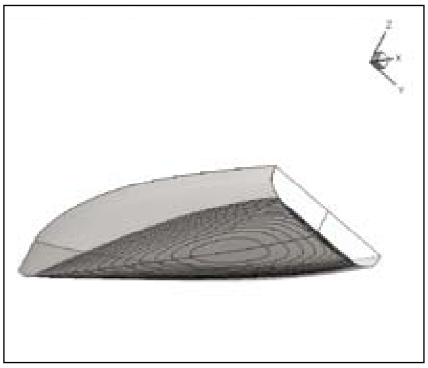
Groupe Finot has designed the winner of every Vendée Globe except the 2008/2009 edition, in which its fastest 'Open 60' finished second behind a design from the USA. According to Finot, there is a dearth of knowledge about the influence of hull shape on the performance of planing sailboats such as Open 60s, forcing designers to rely on intuition. Each generation is lighter and more powerful than its predecessors, which implies previous experience may not be relevant to new designs. In the introduction to his PhD report, Raymond points out that existing design tools such as velocity performance prediction (VPP) do not cover planing speeds; and that current theories of planing hull design were developed for powerboats, which do not heel, and which operate in a narrow range of speeds. Offshore racing yachts sail upwind at heel angles of at least 30 degrees, and they are expected to make effective use of winds so light they barely make headway. Further complicating the problem, they are driven by a power-plant that varies continually, and which often generates more side-force than forward thrust. It is no wonder that the development of a new-generation racing yacht usually requires a detailed tank testing campaign that consumes a sizeable chunk of the overall design and construction cost.

Raymond set out to develop a simpler and less expensive design tool for planing yacht hulls. It would be based on information drawn from a systematic series of hulls. The software would estimate the performance of a new hull shape by interpolating from the known behaviour of several related hulls.

The modern planing keelboat has evolved a unique shape that seems well-adapted to its role. Beyond the fact that they are sharp at one end and blunt at the other, the latest Open 60 hulls are nothing like typical cruiser-racer hulls, nor are they very much like skiffs, which are generally sailed flat, not heeled. The new hull series should be developed from recent planing keelboat hulls. It would also cover a range of shapes that might be suitable for next-generation designs, which would be lighter than present-day boats because they would be built from more advanced materials.

When Raymond visited Auckland in December 2008 for the Royal Institution of Naval Architects (RINA) High-Performance Yacht Design conference, he had been thinking about how he might create this systematic series of hull shapes. He needed a system that would integrate well with computational fluid dynamics (CFD) applications, so it was essential to use software that would produce a fair surface. Only specialist hull modelling software would do. But he knew it would be a tedious and time-consuming task to create his hulls with existing yacht design software.

That was before he heard about the Friendship Framework and the kspline. The kspline was developed by the author, New Zealand yachtsman and writer, Kevin Cudby. It was designed for creating parametric section curves for yacht hulls. From Raymond's perspective, it was interesting because its shape is controlled by the values of a small number of parameters. Used as an underwater section, the curve is defined by its breadth, depth, cross-sectional area (with respect to a horizontal datum such as a waterline), deadrise angle, and two parameters that control the curvature in the floor and bilges. Adjusting the value of any parameter modifies the shape.

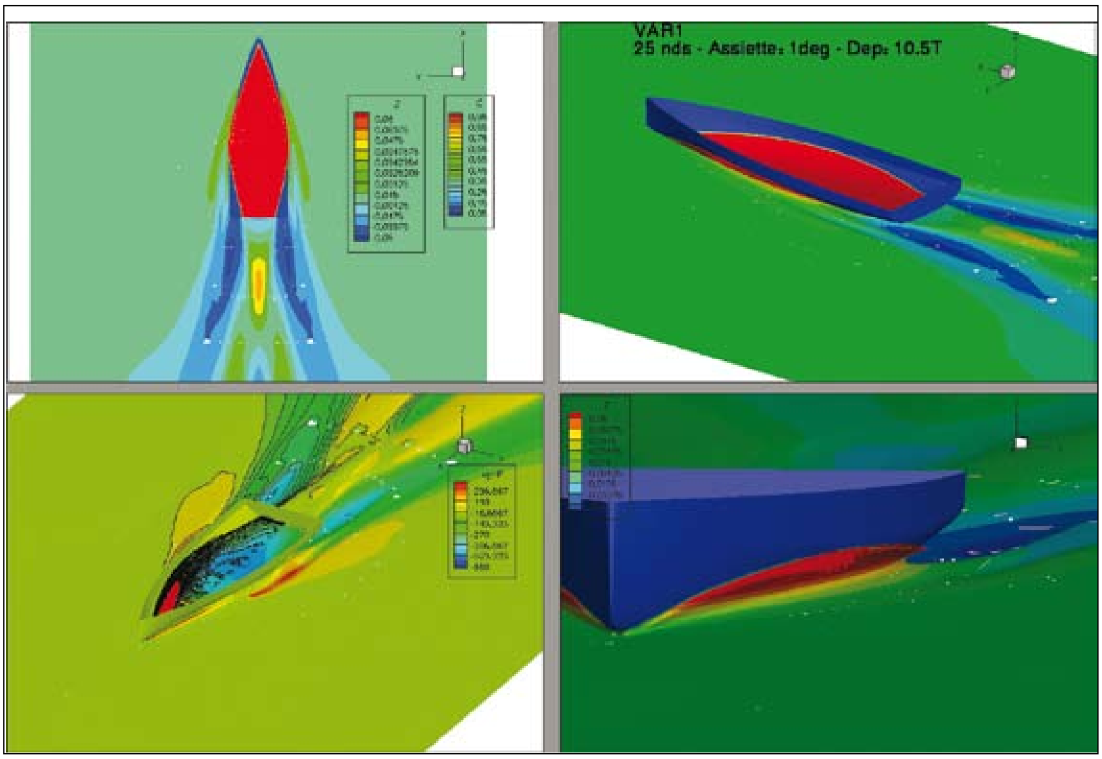


Hull number 14 from Raymond's systematic series (Credit: Jérémie Raymond).

The author attended the conference to introduce his invention to the yacht design community. Over the previous year, he had worked with Potsdam-based Friendship Systems GmbH to implement the kspline in the Friendship Framework, a parametric hull modelling and computer-aided engineering (CAE) system. This system was an ideal host for the kspline, because it allows a designer to define a hull shape by creating a set of lines, such as waterlines and sections. Crucially, this software skins the designer's framework with a set of faired bspline surfaces, fully compatible with industry-standard analysis, design, and manufacturing software. Testing and practice had shown that the kspline integrates well with Friendship's existing design tools, including the fspline, a fair two-dimensional curve.

The author's demonstration was based on a medium-displacement cruising yacht hull. To show how a designer might use the kspline, he created a family of six hulls. All of these hulls shared the same centreplane and waterline curves, and because he did not alter the immersed area of any section, all six hulls had the same nominal displacement. Heeled at 30 degrees, their waterlines showed noticeable differences.

But that was not what captured Raymond's attention. The demonstration hulls had been created on a low-cost laptop computer: The little number-



CFD simulation of hull number 1 at a trim angle of one degree, and a boat speed of 25kts (Credit: Jérémie Raymond).

cruncher had done it in 12 seconds. The kspline would eliminate much of the tedium usually involved and allow Raymond to spend a great deal more time investigating the performance of his hulls, which was, after all, the main object of the project.

The project presented a unique set of requirements and this was reflected in Raymond's framework of sections and longitudinal lines. He wanted to study the dynamic performance of his hulls, so the position of the static waterline was far less important than dynamic lift and trim. The hulls were based on the latest (2007) Groupe Finot Open 60 hulls, which feature a pronounced knuckle or chine in the topsides. So, whereas the section curves in the author's demonstration model were referenced to the design waterline, Raymond referenced his kspline sections to the chine.

In other respects, Raymond's framework resembled the demonstration model. The values of various kspline parameters are defined by smooth longitudinal curves or straight lines, which define the value of a parameter as a function of the position along the length of the hull. The longitudinal centreplane curve is a pair of ksplines (one forward, one aft). Other longitudinal lines, such as the chine and sheer, are fsplines.

The complete model was defined by 40 numbers, or 'parameters'. Changing the value of any parameter will change the hull shape. Raymond created a series of 15 hulls by varying the values of key parameters, such as the curvature of the aft centreplane curve.

Creating a series of hulls was only the first step of a complex project. The next step was to measure their performance under various conditions. The parent hull was an Open 60 designed in 2007 by Groupe Finot, and used in four 2008/2009 Vendée Globe competitors: *Generali*, *Hugo Boss*, *DCNS*, and *BritAir* (which eventually finished second). Its performance had been characterised by an extensive tank-testing programme, and the tank-testing model was available for further testing.

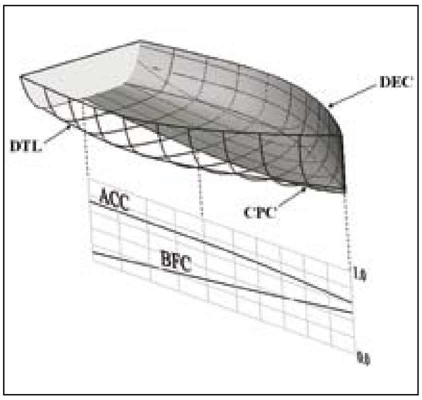
Rather than build a series of new tank-testing models, Raymond chose to analyse the hulls using a CFD code. The results could be validated by comparing the CFD analysis of the parent hull with measurements from the tank testing programme. After evaluating several CFD systems, he selected ISIS-CFD.

Data from the CFD analysis was used to develop a VPP system based on regression formulae. Whereas the CFD analysis takes many hours to calculate the performance of one hull under one set of operating conditions, the VPP can provide more or less real-time estimates of a hull's potential behaviour. This means that small, limited-budget projects can benefit from the results of a detailed programme of CFD and tank-testing, via the VPP system.

Raymond's VPP remains a work in progress. The project confirmed that RANS-VOF CFD codes are capable of predicting the performance of planing hulls. Relative to tank test data, ISIS-CFD produced realistic results up to a Froude number of 1.2, equivalent to about 31kts on an Open 60. But the hulls were analysed only at one value of displacement, and the analysis did not investigate their heeled performance.

Even so, Groupe Finot has already pressed the new VPP into service. Its first serious application was a 3.6m dinghy, the prototype of which was built in October 2009. According to Raymond, the ability to rapidly develop a systematic series of hull shapes was critical to the success of the project. Asked how he would have done it, without the kspline and the Friendship Framework, he said: "I can't imagine." ***SBI***

Tank testing the Groupe Finot Open 60 (as used on *Generali*) the parent hull for Raymond's systematic series (Credit: Jérémie Raymond).



A hull framework with one side of the skin omitted. Area coefficient curve and bilge factor curve specify the values of section shape parameters as a function of longitudinal position. Overall section dimensions are defined by longitudinal curves such as Deck edge curve, Datum, and Centreplane curve. Raymond's hull series was based on a similar, but more complex, framework.