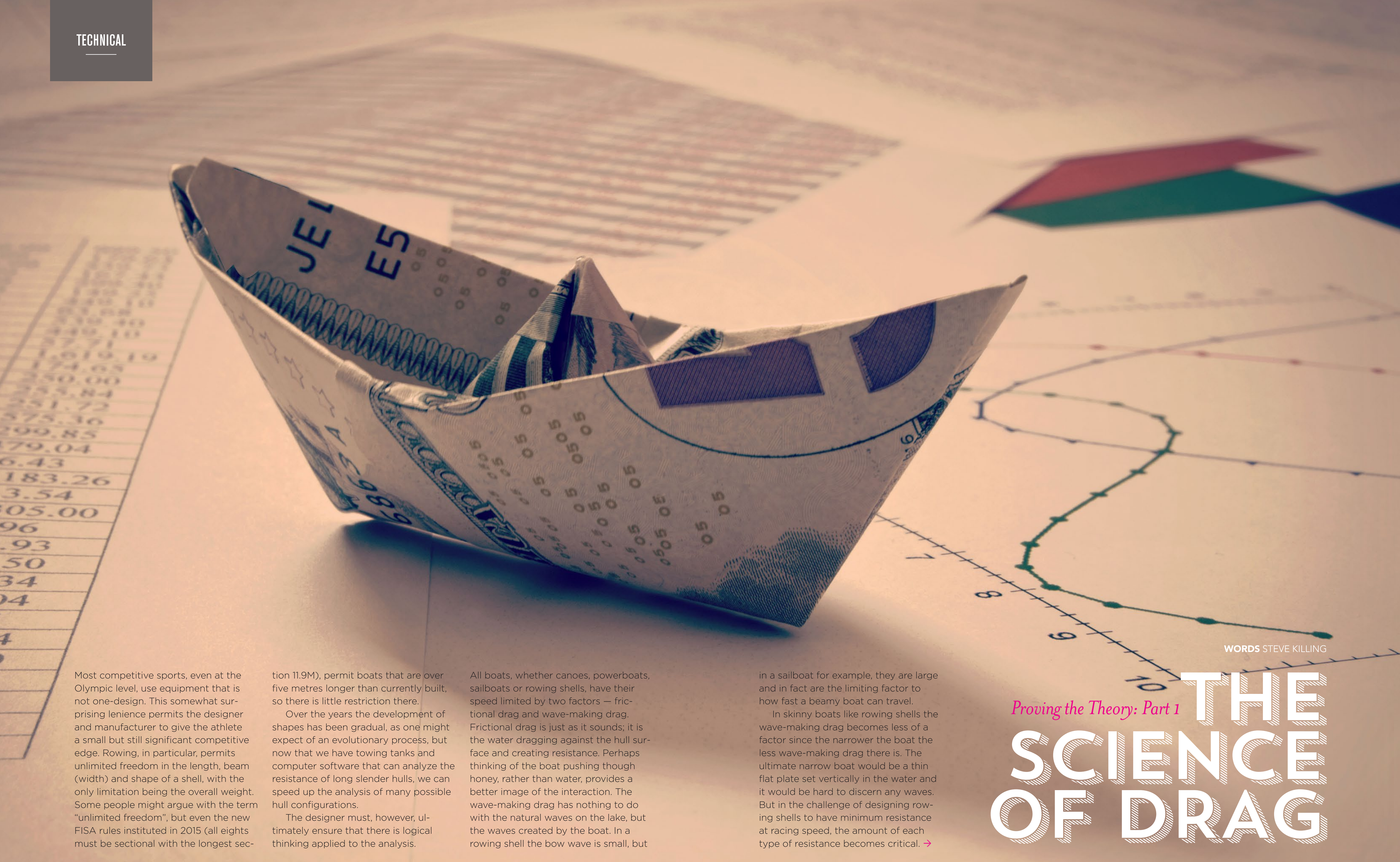

WORDS STEVE KILLING

Proving the Theory: Part 1

THE SCIENCE OF DRAG

Most competitive sports, even at the Olympic level, use equipment that is not one-design. This somewhat surprising lenience permits the designer and manufacturer to give the athlete a small but still significant competitive edge. Rowing, in particular, permits unlimited freedom in the length, beam (width) and shape of a shell, with the only limitation being the overall weight. Some people might argue with the term “unlimited freedom”, but even the new FISA rules instituted in 2015 (all eights must be sectional with the longest section 11.9M), permit boats that are over five metres longer than currently built, so there is little restriction there.

Over the years the development of shapes has been gradual, as one might expect of an evolutionary process, but now that we have towing tanks and computer software that can analyze the resistance of long slender hulls, we can speed up the analysis of many possible hull configurations.

The designer must, however, ultimately ensure that there is logical thinking applied to the analysis.

All boats, whether canoes, powerboats, sailboats or rowing shells, have their speed limited by two factors — frictional drag and wave-making drag. Frictional drag is just as it sounds; it is the water dragging against the hull surface and creating resistance. Perhaps thinking of the boat pushing though honey, rather than water, provides a better image of the interaction. The wave-making drag has nothing to do with the natural waves on the lake, but the waves created by the boat. In a rowing shell the bow wave is small, but in a sailboat for example, they are large and in fact are the limiting factor to how fast a beamy boat can travel.

In skinny boats like rowing shells the wave-making drag becomes less of a factor since the narrower the boat the less wave-making drag there is. The ultimate narrow boat would be a thin flat plate set vertically in the water and it would be hard to discern any waves. But in the challenge of designing rowing shells to have minimum resistance at racing speed, the amount of each type of resistance becomes critical. →

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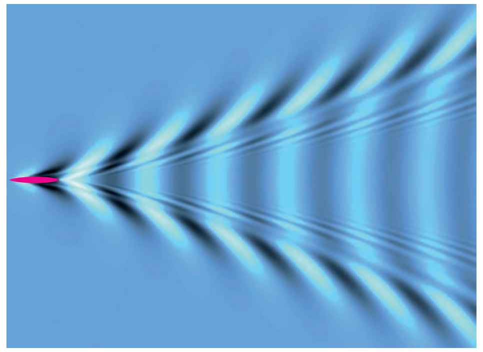
Fig. 1

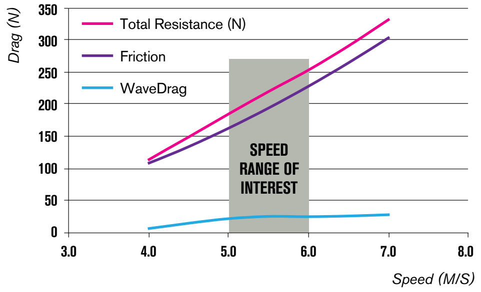
The top blue shell has a bias towards reduced frictional drag while the longer orange shell keeps wave-making drag to a minimum.

Fig. 2



A typical wave plot showing transverse waves behind, and divergent waves emanating from the bow, for a narrow hull.

Fig. 3



Upright Resistance versus Speed
Frictional Drag dominates the overall drag in a rowing shell. In this example 4 person shell 88% of the drag is due to wetted surface friction. (Predictions made with Flotilla software)drag to a minimum.

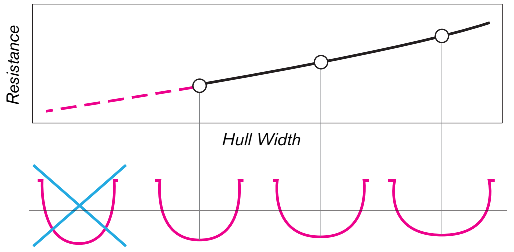
If frictional drag were the only component of concern, the boats would be very short to keep the surface area touching the water (the wetted surface) to a minimum. If wave-making drag were the only drag, the boats would be very long to keep them narrow and the waves they produce small (see Figure 1). The reality is in between these two, but optimizing the length requires a rather exact knowledge of the value of each type of resistance. A comparison of different manufacturer's products in your boathouse can show variations of a metre or more in length, all designed for the same class and weight of rower. Different theories and varying experience levels have led to different conclusions.

The components of frictional and wave-making resistance for a typical four-person shell are shown in Fig.3. It can be seen that the contribution to overall resistance due to wave-making drag is very small, in the order of 12% of the total at a normal racing speed of 5.5 metres/second. The initial reaction of the designer to optimising this boat might be to concentrate on keeping the wetted surface to a minimum as it is creating most of the drag. That is true but the subtlety of the trade-off of those two factors with length is very important and sometimes surprising.

The shells that you row have been designed to give minimum drag for a given weight and skill level of crew. A novice crew will row faster in a boat that has greater stability than one designed for an experienced crew. In order to optimize the length of a shell during the design process, the fixed parameters must be set carefully. We must consider not only minimising the drag of the hull, but setting a minimum internal width of the boat to accommodate the crew and setting a minimum permissible stability that we know the targeted crew, experienced or intermediate, can handle.

The consideration of stability has a marked effect on the outcome of such a study. In my experience, for a given length of hull, a rowing shell can always be made faster by making it narrower (and a bit deeper). However, doing so will take the stability below the acceptable value for the crew. So the minimum resistance is governed by the stability of the boat. In performing a length study, therefore, for each length the minimum resistance will be achieved by the narrowest boat that will still offer the required stability for the crew.

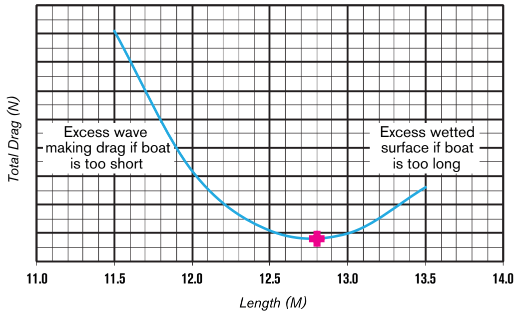
Fig. 4



For a given hull length, variations in width and depth are plotted below their total resistance. The left hand hull although it has the lowest resistance, is below the allowable stability and therefore does not qualify to be part of the optimized length study.

Fig. 5

MINIMUM TOTAL DRAG VERSUS LENGTH
At each LOA, Target MetaCenter Ht and Min R has been met
At V= **5.0 m/s**



Minimum Total Drag versus Length
A plot of Drag versus Length illustrates that there is a penalty in designing too long (too much wetted surface) or too short (too much wave drag).

In Fig.5 you can see the total drag of a series of shells with the same crew weight, but with varying lengths. The width, out of necessity, must increase as the length reduces in order to keep the volume and therefore the load capacity the same. The plot of total drag versus length shows there is an optimum length for this particular weight class of shell.

At this point we need to be cautious about final decisions for the parameters of a new boat. It is important to know the theory behind, and limitations of, the particular software being used. Since the trade-off between frictional and wave-making drag affects our choice of a longer or shorter boat, the software's assessment of those factors is important. We have done careful validation of the computer code that we use and each manufacturer will have done the same. One must understand when to accept the predictions at face value and when to use other tools to assess the performance.

This optimal length analysis is unique for a given crew weight and that leads to most manufacturers having several weight categories and lengths for each type of rowing shell. With careful use of software and some way to validate the drag that it predicts, the designer can create a rowing shell of minimum resistance, giving the rowers a small advantage to take into every race. ROW360

Next issue: We'll have a look at a Tank Testing experiment of two doubles used to validate the computer software.

A Study to Help Understand the Effect of Crew Weight on Stability

If your crew were to row the same boat that my crew had just vacated, the stability would not only feel different, it would actually be different. Perhaps it seems illogical, but the same hull will have a different stability depending on the weight of the crew rowing it. As the rowing shell is loaded more heavily and sinks lower in the water the stability is reduced. This is counter to the experience of sailboat owners who may add ballast to their boats to make them more stable. The difference here is that the weight we are adding is the crew, a moveable weight well above the centre of rotation of the hull.

When a lightweight eight is taken for spin by the mid-weight men, they may have trouble setting it up. Shells are designed for a given weight class and typically if you are lighter than the intended weight class for the boat you will find it easier to balance. If you are heavier than the weight class the boat is designed for and are an experienced rower, you may be able to set up the boat and row well or the shell may now be too unstable to row efficiently. Being aware of the stability change with varying crew weights may help you and your coach better understand how a boat feels on the water.

***Steve Killing** is a yacht designer and avid rower based in Midland, Ontario, Canada, who designs for HUDSON. You can see the racing sailboats (multiple C-Class Catamarans and America's Cup), canoes, kayaks, and classic mahogany runabouts that he has designed at www.stevekilling.com*