BY JB BRAUN

Finely Tuned Spinnaker Trim

Computer analysis helps us understand when it's fast to ease the spinnaker sheet until the luff curls.

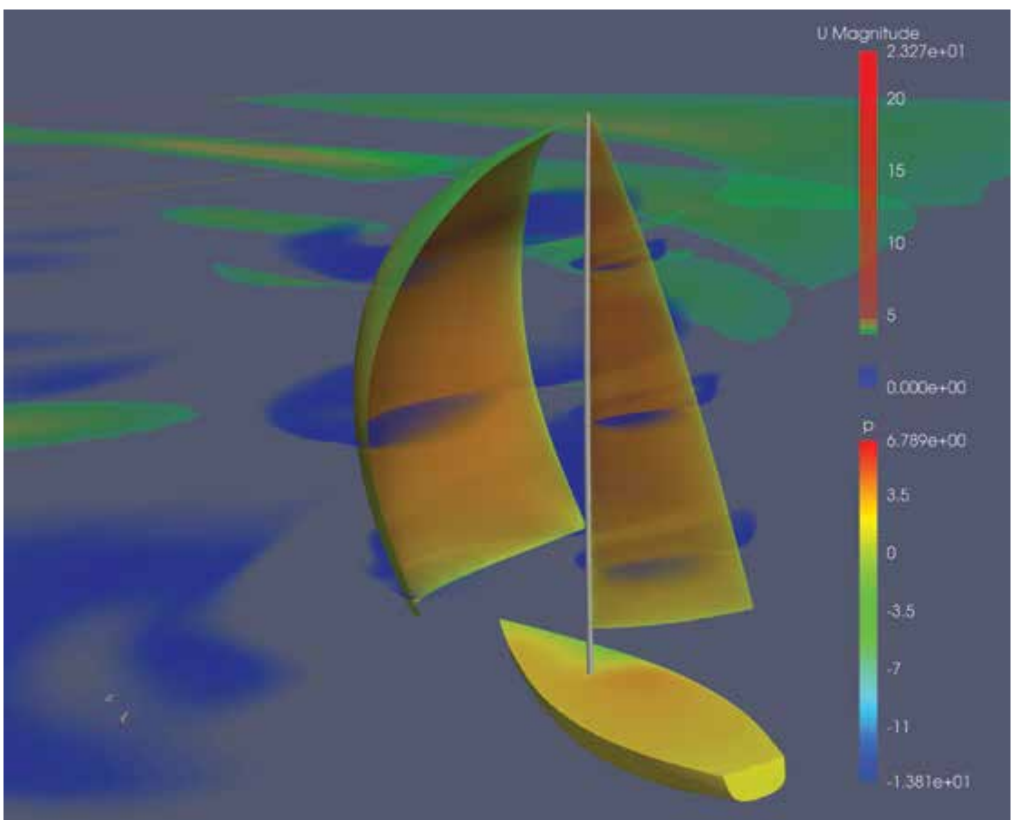
● The primary advice for spinnaker trimmers today is the same as it was 50 years ago: "Ease the sheet until the leading edge begins to curl, then trim in slightly. And repeat." As a sail designer immersed in the science of how to make and trim fast sails for most of my life, I find the technique more than a little disappointing. Doesn't modern technology have a little more to offer when it comes to the art of making a boat sail fast downwind?

Yes, it does. The Sailing Yacht Research Foundation partnered with North Sails in a two-part study to help predict the force and moments generated by gennakers and spinnakers. The study, known as Downwind Aero Moments and Forces Project, allows handicap rule-makers to better understand performance trade-offs associated with different downwind sails. The research allowed the opportunity to bring the specifics of downwind sail trim into sharper focus.

Computer analysis of upwind sail trim is nothing new. Because sail materials are stiffer and the shapes flatter and relatively stable, upwind sail performance can be accurately modeled with straightforward computational fluid dynamics. Downwind sails, however, are relatively stretchy and operate at much lower windspeeds, so the propensity for the airflow to stall, or separate from the sail, is much higher. A spinnaker is anchored only at the corners, so the sail moves around more, and as a result, trimming must be more dynamic. While it's standard to cleat off a jib sheet, a good spinnaker trimmer is constantly working the sheet. Accounting for how and why a spinnaker moves, and how that impacts shape, airflow and many other factors, is a challenge with which we've only recently started to come to grips.

Before we get too deep into the topic, let's review a few fundamentals of aerodynamic terminology. The two major forces acting on any wing are lift and drag. Drag always acts in the direction of the wind, while lift is the force component perpendicular to the drag.

The forces on a sail are the



A simulated look at a spinnaker shows pressure distribution and air flow velocity. Yellow indicates neutral pressure, red is positive pressure, and green is negative pressure on the sail. Of the horizontal slices blue represents stalled air and green represents positive airflow.

same, only the wing is vertical. Flow over the sail is generated by apparent wind, which is a combination of the true wind and the airflow created by forward movement of the boat.

When sailing upwind, the relationship between lift and drag is simple. Lift from the sails, balanced by lift from the keel, helps to drive the boat forward. Drag, pointed in the direction of the apparent wind (25 degrees off centerline for an average keelboat), is working almost directly counter to forward progress. The trimmer's goal is to maximize lift and minimize drag.

As the boat bears away and apparent wind swings aft, the relationship changes. With the apparent wind 90 degrees to the boat's centerline, lift is providing the driving force that pushes the boat forward, whereas drag is working to heel it to leeward. As the boat turns farther downwind, the direction of lift shifts to weather, while drag gradually comes more in line with the intended direction of the boat. When a boat is dead downwind, drag provides all the drive force, and lift becomes the heeling force to weather.

With this in mind, let's take a look at two different points of downwind sail to see if modern science can get a little deeper than the time-honored advice mentioned at the start of this story. To isolate the spinnaker, we locked in the onset flow (apparent windspeed and angle) and the mainsail trim, and varied only spinnaker trim. As one might expect, for any given apparent wind angle and wind strength, there's an optimum trim for the spinnaker. Ease too much, and the leading edge begins to fold and drive force is reduced. Trim too much, and the sail stalls, and flow and pressure drop, which also reduces drive force. Anyone who's spent more than a few minutes working a spinnaker sheet knows these basics, regardless of whether they know the terminology or understand the science.

How fine is that groove of optimum trim? How much do you actually lose by not having optimum trim? And how much does this vary depending on the point of sail? For these answers, we turn to the computer.

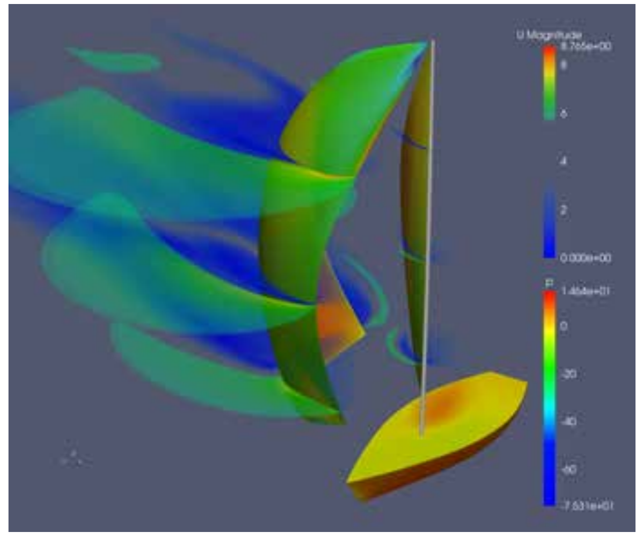
TIGHTER APPARENT WIND ANGLES

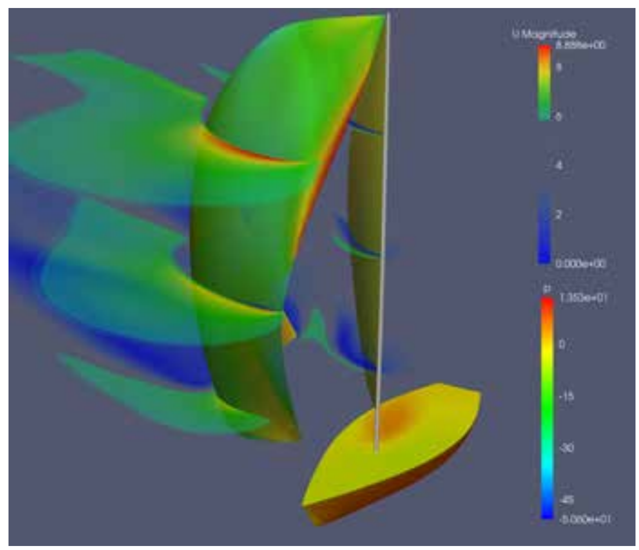
In moderate wind speeds, a modern sprit boat often finds the best VMG toward a leeward mark at an apparent wind angle of approximately 85 degrees, or just forward of abeam.

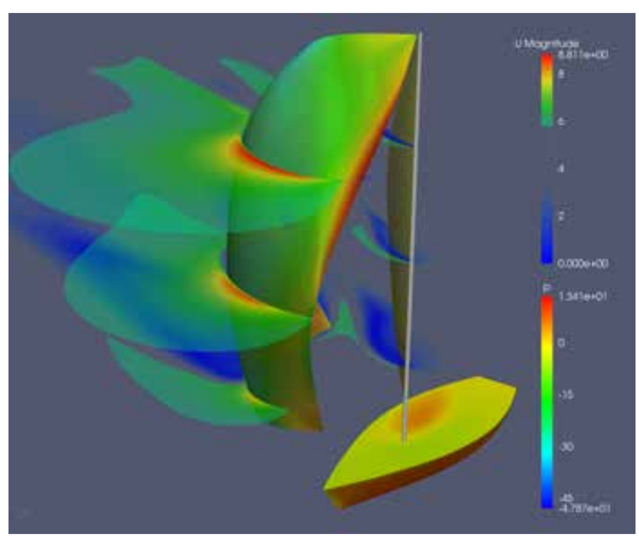
The diagrams allow us to look at lift and drag somewhat independently. Pressure on the spinnaker is indicated by the color of the sail: Yellow indicates neutral pressure, red indicates positive pressure, and green indicates negative pressure. These colors are specific to the side of the sail shown in the diagram. If you're looking at the inside of the sail, positive pressure — indicated by red and orange hues — keeps the sail full and pulling the boat forward.

The three horizontal slices in each image are colored to indicate wind velocity, with blue representing stalled air, and green to yellow to red representing airflow of increasing velocity. The images are arranged clockwise from the top left from tightest trim to most eased.

As expected, the tightest trim has the slowest-moving air around the sail surface. The large areas of blue and green indicate stalled air across most of the sail's cross section because the wind is not flowing across the full width of the sail. As with an airplane wing, stalling a sail results in a sudden decrease in lift and an increase in drag. The most eased trim setting has the fastest-moving air around the sail surface, but it also has the







At an apparent wind angle of 85 degrees, the danger is in trimming too aggressively. The trio of images at right is a look at the pressure and airflow velocity for optimal trim (middle) as well as slightly over (top) and under trimmed. The significant amount of stalled air in the top image (shown in blue on the horizontal slices) creates drag, which pulls the rig sideways, since drag is always in line with the apparent wind. The bottom two images have less drag and more attached flow — note the thin horizontal slices of yellow and red along the outer surface of the spinnaker — which generates maximum lift and pulls the boat forward. The red strip along the luff of the spinnaker represents the curl.

largest amount of reverse pressure (indicated by the largest area of red) of curl to the sails luff. The middle image is the ideal trim for this point of sail.

The most valuable piece of information isn't the shape of the sail at the ideal trim, but rather what happens when you're a little off ideal trim. If you're a little too eased, the drive force drops off, but not nearly as aggressively if you're too tight. When you overtrim the spinnaker on this point of sail, the decline in the drive force happens much quicker.

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DEEPER APPARENT WIND ANGLES

As a boat closes in on dead downwind, where the kite is excessively rotated to windward, drag becomes a bigger component of the drive force, while the importance of lift diminishes. This explains why the trimming groove is more forgiving at 170 degrees apparent. When you overtrim, you get less lift but more drag. When you overease, the spinnaker generates more lift but less drag.

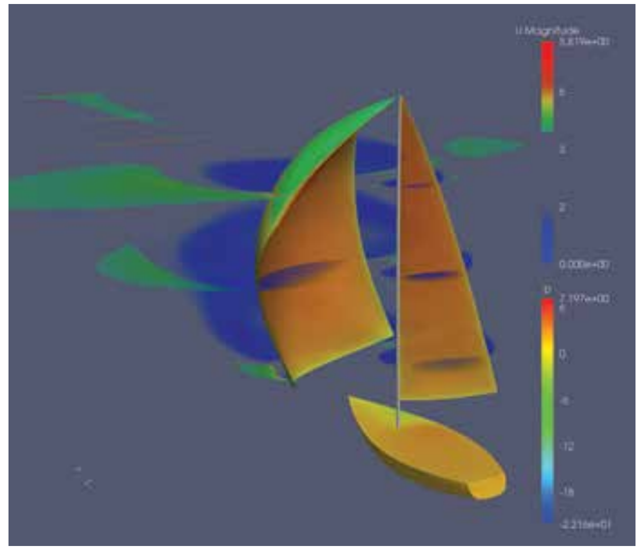
The drive force at AWA 170 is less pronounced than it is at AWA 85. This happens because at deep downwind angles, the sail is predominantly stalled, and the aim is to maximize drag. However, when stalled, the sail no longer accelerates the flow and instead acts like a drag blanket, which explains why sail trim matters less at this angle.

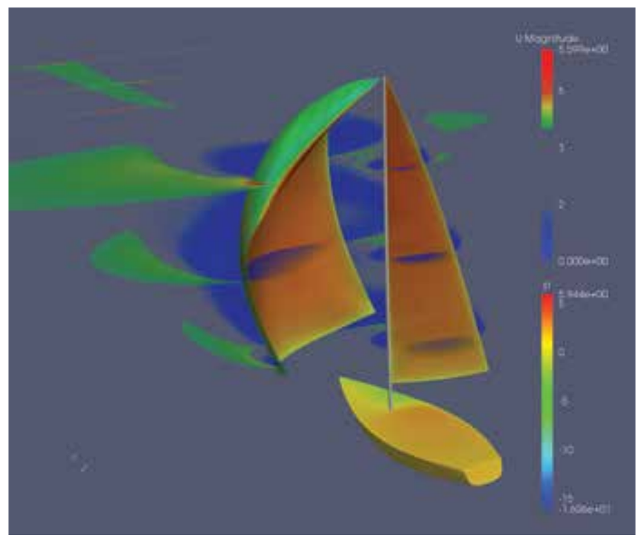
Again, let's look at the pressure and flow simulations, with the tightest trim at the top. As the sheet is eased, the sail begins to generate lift because the flow is less detached and thus accelerates. However, because lift is perpendicular to the apparent wind angle, added lift at this angle serves mostly to pull the rig to the side and doesn't do much to increase the drive force. At our maximum amount of ease, the flow is moving over the sail quickly, which means there is less drag and consequently less drive force.

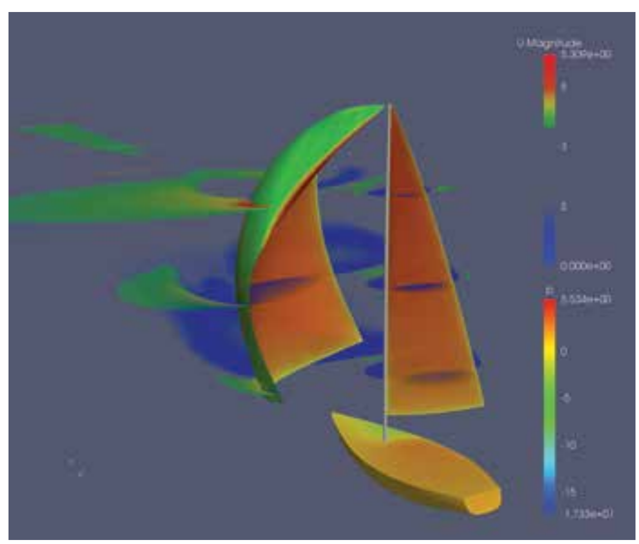
The above two cases illustrate the most extreme ends of trim. At broad reaching angles (AWA 85), the goal of spinnaker trim is to generate as much lift as possible with as little penalty from the resulting drag. At deep downwind angles (AWA 170), the goal of spinnaker trim is to maximize drag while benefiting from a wider groove of optimal trim.

Does this mean you can toss out all you've ever heard about spinnaker trim? Hardly. Those old maxims have endured for a reason. Working the curl is still an acceptable way to trim a spinnaker. However, hopefully you can now trim the sail with a more nuanced understanding of what the curl means for optimal sail trim. For tighter apparent-wind angles, the most drive force and optimum trim exists when the luff starts to curl. For deeper apparent wind angles, the optimum trim occurs before the luff curling.

Author's note: Michael Richelsen and Erik Weis aided with the research, which was done in collaboration with the Sailing Yacht Research Foundation.







At an apparent wind angle of 170 degrees, drag becomes a valuable contributor to boatspeed since it's now in line with the boat's heading. The slightly over trimmed spinnaker (top) generates the most drag while the under trimmed spinnaker (bottom) has better flow over the sail but significantly less drag than the optimal or over-trimmed settings. The trimming groove is wider at this deep angle, but a good trimmer will err on the side of keeping the curl out of the luff and maximizing the drag.