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MAXIMUM SAIL POWER

CHAPTER 6

WHERE ART AND SCIENCE MEET - Part 1

Chapter 6 is an in-depth look at the sailmaking process from how we used to make to how they are made these days in a modern sail loft. There is a lot to cover from basic design elements like sail geometry and engineering to a look at the manufacturing process. There will be three parts to Chapter 6 starting with this one that covers some of the elements of sail design.

A look at the sailmaking process

The basic tools of sailmaking are no longer the stuff of charm and tradition. Where bolts of sailcloth, spools of wax thread, and hides of tanned leather once filled corners of sail lofts, and old men with character lines in their faces and stories to tell worked their craft, there are now talented young men and women operating high-powered computers. Gone too are the large open wooden floors marked with awl holes and chalk marks with patterns drawn on the varnish and templates hanging on nearby hooks. Instead, there are laser cutters and plotting machines whirring quietly off to the side, while efficient workers assemble sails on lofting tables. I fell in love with the old sail lofts and wonder if I would have been as intrigued with the business of sails had I come upon it in recent years. Certainly something is missing, although then again nothing ever remains the same, and a loss for some has been a gain for others. Sailmaking has evolved and has made extraordinary gains since computers became readily available. Still, because of the nature of sailing and the infinite variety in the forces encountered out on the water, some art remains in the process. At least I choose to think so. Despite the advances and no matter what the sail, the sailmaker's job remains the same: to take flat fabric and turn it into a three-dimensional aerodynamic foil that will hold its shape through a variety of wind conditions. Even with miracle fibers and computer programs this is no easy task given the number of variables. Fabrics that stretch, rigs that bend, and sailors with differing opinions of what looks right all make the job more complicated. It was only once the stretch characteristics of fabrics became predictable that sailmakers were able to build upon empirical data gained by experience. Up to that point they had to start anew with each new bolt of sailcloth since they had no idea how the fabric might stretch and how their design should compensate for this distortion. It

Sailmakers palm and sewing needle - still being used.

was only after this variable was eliminated that they could begin to build upon the design information they already had. If a new luff curve or chord depth ratio proved faster, for example, that information could be repeated and improved upon. This incremental improvement eventually led to sails that were lighter, more efficient, more durable, and easier to use. But it took a long time, at least by modern standards, and could often be prohibitively expensive for all but the wealthiest sailors. In fact, a benefit of modern technology is that, factoring in inflation, sails are actually cheaper today than they were a few decades ago, and they last longer.

The Design Process—Turning Theory and Fabric Into Flying Shapes

Each sail goes through a number of design steps before construction can begin. Some steps, like sail geometry or the basic shape of the sails, are reasonably simple while others, like computing stress/strain pictorials, require much more thought and deliberation. Ultimately, the shape of each sail will be drawn from a database of known sail designs and manipulated until the designer is satisfied that the sail he is creating for your boat is perfect for your purposes. Before we look at the various steps involved in sail design, we need to first look at some of the design features the sail designer is aiming to achieve. These features are important to the overall success of the sail and are basic to all sail designs.

Chord Depth or Sail Draft

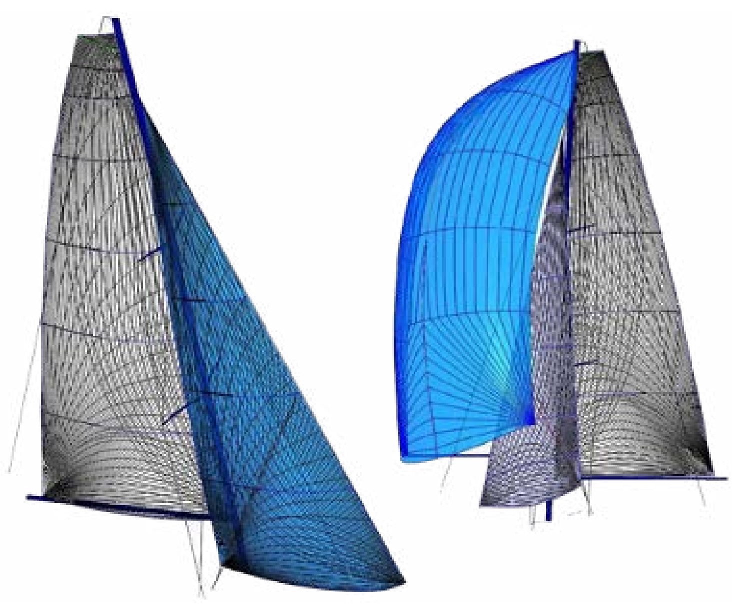
This is probably the single most important feature of any sail. The chord depth, also called the camber or draft, is determined by running an imaginary line or "chord" from the luff of a sail to the leech, and then measuring the distance from this line to the deepest part of the sail. The "chord-depth ratio," often expressed as a percentage, refers to the ratio between the length of the chord and the depth of the sail. Because sails taper toward the head, it is important for the draft of the sail to be expressed in terms of a ratio rather than a measurement. A depth of 18 inches in the body of the sail could be seven inches toward the head and still have the same chord-depth ratio. Note that chord depth can be adjusted by the way you set your sails and that there is no one chord depth that is perfect for all conditions. Rather there is a chord depth that is right for a given set of conditions taking into account wind speed, wind direction, wave heights, the kind of boat you are sailing, and so on. One of the main goals of sail trim is to match the chord depth with the conditions to provide an optimal performance. This will be covered in more detail in the chapter on sail trim.

Different chord depths are important for different wind conditions in order to keep the flow of the wind attached to the sail. As a general rule of thumb, full sails (read lower chord-depth ratios) work better in light winds, and flatter sails (read higher chord-depth ratios) work better in medium to heavy winds. Using a full sail in a lot of wind will cause the fast-flowing air to separate from the sail. Flat sails can also work well in extremely light winds since they make it easier for the air to remain attached to the sail. If you try to make the sail too full there is simply not enough wind for the flow to even get around the corner, let alone to the leech.

The second element in the chord-depth equation is the location of the maximum depth relative to the chord: In other words how far back from the luff is the point of maximum depth? This amount is also usually expressed as a percentage and is important because it is crucial in determining the overall aerodynamic shape of the sail. In headsails, the maximum chord depth should be roughly 35 to 38 percent aft from the luff, while for mainsails the maximum chord depth should be around 45 to 50 percent aft. The chapter on sail trim will be more specific on where to place this point of maximum draft as well as chord-depth ratios.

Twist

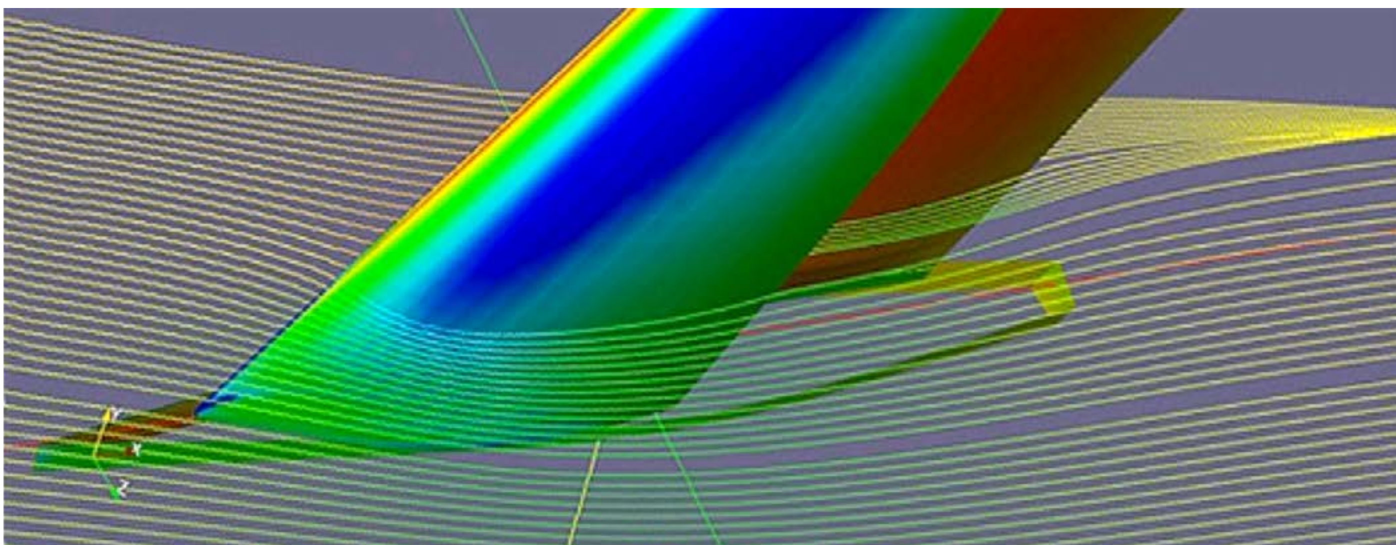
Any surface, no matter how smooth, presents an area of friction to the air passing by it, and water is no exception. When wind blows across a body of water the surface friction slows the speed of the air molecules closest to the surface leaving those particles higher off the water traveling at a higher velocity. Some scientists believe that over a height of 60 feet there can be as much as a 50-percent gain in wind speed. With this increase in speed comes a change in apparent wind angle, i.e., the angle of the wind relative to the orientation of the boat as it moves through the water. We will learn more about apparent wind speed and its effect on apparent wind angles in the chapter about sail trim, but for now this is a brief description of the difference between the two.



Another element of apparent wind is its angle relative to both a boat and the angle at which it is sailing since any change in wind or boat speed will have an effect on the angle at which the wind comes into contact with the sails. For example, when there is an increase in true wind speed, the apparent wind angle will be pulled more toward the direction of the true wind . In other words, the apparent wind angle will increase.

As you get higher off the water there will be more wind and therefore a larger wind angle so that, for example, when the bottom third of your sails is sailing hard on the wind the top third may be sailing on a close reach. If you want the whole plane of the sail to be efficient you need to turn or "twist" the plane higher in the sail to account for the increase in wind speed and change in wind angle. This is the essence of twist and the reason why sails need to be designed accordingly.

This twisting of the wind should not be confused with wind shear, a sudden change in wind speed or direction that occurs naturally in some weather systems.



Twist will always occur; shear might sometimes occur, and when it does you will need to trim your sails accordingly. Note that a natural twist occurs when a sail is sheeted on tight, whether or not it is part of the original design. This is because the part of the sail closest to the point of attachment, i.e., the sheet, will be more directly influenced by the sheet than that part of the sail that is further up the leech. In other words, the higher you go, the less influence there will be on the sail and the sail will twist open of its own accord.

Vertical Distribution of Depth

As alluded to earlier, a sail designer needs to think about how exactly the camber is to be distributed throughout the sail. At first glance one would assume that the camber is evenly distributed from head to foot, but that is not the case. As a general rule, sails have more depth at the head and less at the foot. In order to fully understand this design requirement, we need to take a closer look at yet another significant detail that comes into play when a boat is sailing, a phenomenon called "induced drag."

Part 2 of Where Art and Science Meet will cover more of the sail design process. An in-depth look at all the factors that sail designers and engineers look at when designing your sails.

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