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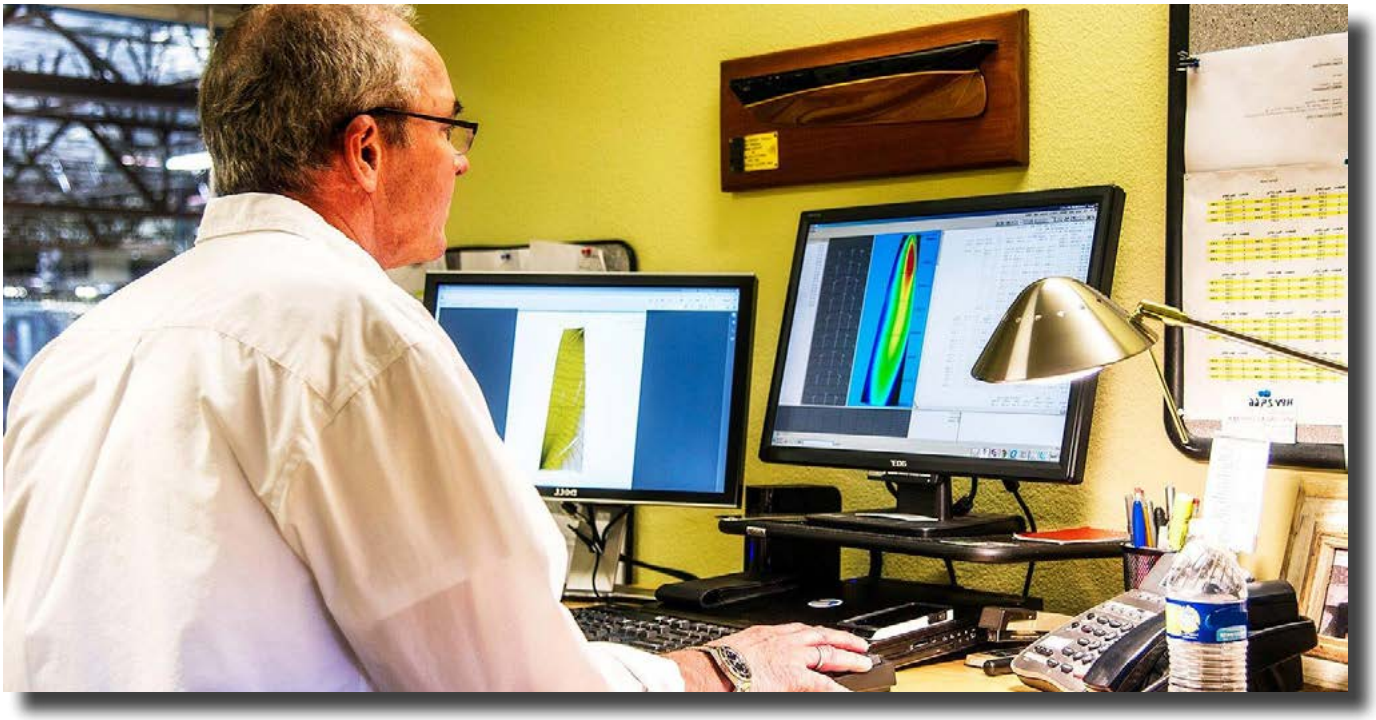
MAXIMUM SAIL POWER

CHAPTER 6

WHERE ART AND SCIENCE MEET - Part 3



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 four parts to Chapter 6. This is part 3 that is all about how sail designers . I urge you to download Part 1 and 2 as well as Part 3 and 4 when they are published so that you will have a comprehensive knowledge of sail design as well as the manufacturing process which will also be covered.

Sail Design 101

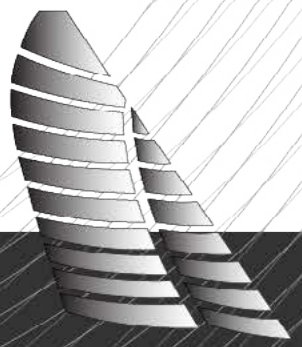
The job facing the sail designer is challenging. He needs to take two-dimensional pieces of fabric and turn them into a three-dimensional aerodynamic shape. It's

a complex process made more difficult by the fact that the force of wind will inevitably strain and stretch the fabric, at least to some degree, out of its initial shape, and while these stresses can be calculated in advance, creating a sail that is able to manage all of the various loads is not easy. The process has been made easier since the advent of stable fabrics and powerful computers, and with data banks of empirical data from which to draw, sailmakers are now able to get the flying shape of a sail close to the designed shape. Bearing in mind that sails will undergo various loads and the design process includes dealing with these loads no matter how they occur, let's start with a blank piece of paper (or more to the point, blank computer screen) and work through basic sail design. We will look at the following steps:

- **Geometry**
- **Sail shape**
- **Analysis**

Step 1 — Geometry

Once the sailmaker has your rig measurement details and understands the kind of sailing you plan to do, he can start the design process by figuring out the geometry of each sail. Perfect aerodynamic shape and engineering amount to zero if the sails do not fit, and this means more than just getting the luff lengths right and having the sail sheet to the tracks. The sail designer needs to take into account details like the location and length of the mast spreaders and where the standing rigging fits into the overall rig plan. For example, he needs to be careful that the design shape for a headsail does not have the sail going right through the spreaders when trimmed for sailing hard on the wind. He also needs to be sure that once the sailor bears away onto a reach that the sail can still be sheeted to the boat. The same points apply to the mainsail. The designer needs to take into account the location of the backstay and design the roach profile accordingly. There is no point in adding roach to the sail and then not being able to tack the sail



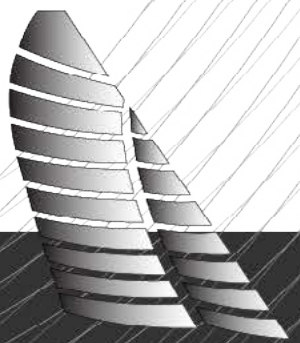
through the back- stay. He also needs to be careful when designing a full-batten mainsail that the bat- ten locations do not coincide with the spreaders, both when fully hoisted and reefed. Point loading a batten on a spreader is looking for trouble.

The kind of sailing you plan to do also plays an important part in the geometry of the sails. If you are strictly inshore racing, the sail designer will keep the clew of the headsails fairly low and have the foot of the sail "sweep" the deck. On the other hand if you are heading offshore it might be useful to raise the clew so that waves can pass under the foot. This will also allow some visibility under the sail. Finally, the sail designer needs to be sure that there is some correlation between the sizes of different sails so that the sailor can reduce sail area and still keep the center of effort of the sailplan in the right location so that the boat remains balanced.

Step 2 — Sail Shape

There are two theoretical design shapes for each sail. The first is the molded shape; in other words, the static shape of the sail before it is subject to any loads. The second is the flying shape, i.e., the shape of the sail after it has been subjected to the force of the wind. The design process incorporates both the molded and flying shapes, and it becomes the designer's job to take both into account before moving on to Step 3, which is the part of the process that analyzes the interaction between molded and flying shapes.

Molded Shape — This shape is usually drawn from a data bank of known sail shapes and serves as a jump-off point for the design process. It is illustrated by horizontal and vertical cross sections of the surface of the sail and the measurements are called offsets. Offsets are a two-dimensional way to describe a three-dimensional curve. These offsets show the important design features of a sail, namely the chord depth, the position of the maximum draft, the angle of leading edge and the amount of twist in the sail. They are created for each section, or horizontal "slice" of the sail. Think of the sail design as a huge stack of

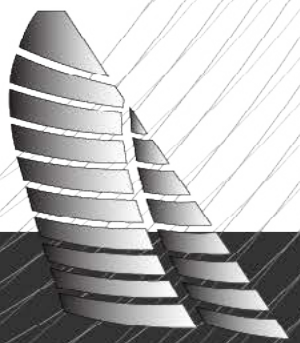


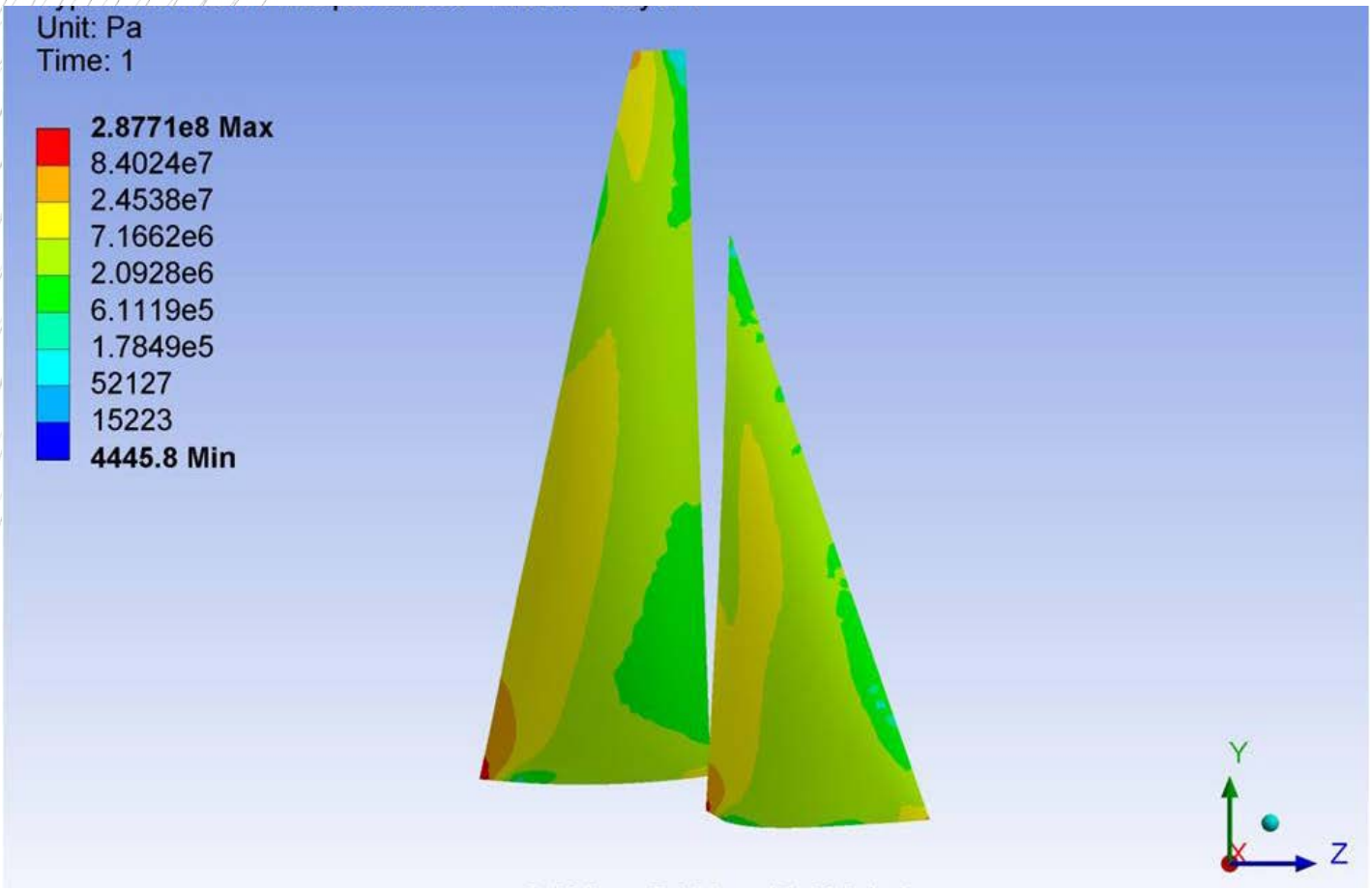
individually created cambered shapes each with its own chord-depth ratio, twist, and maximum depth location. Stacking them on top of each other creates the overall sail shape.

Most sail designers have their own software that allows them to enter the boat's rig dimensions and deck hardware into the actual sail design program. This is fairly sophisticated and can be a great help in terms of the next step in the process, since it allows the designer to manipulate the sail and rig as one, and to address wind-flow issues over the entire plane, not just over individual sails. The mechanical properties of the mast and rigging can also be entered, including moments of inertia and a material's stiffness or resistance to stretch. Using this information, the designer can determine the deformation under load for the sail and every piece of standing and running rigging right down to the stretch in sheets and halyards. This kind of precise information is vital. If halyards stretch or the mast bends more than the designer anticipated, the shape of the sail will be affected. Being able to have some control over parts of the boat previously out of his realm allows the designer to have more control over his design. This control may only be in the form of knowing what to expect and designing the sail accordingly, but in any event it's useful knowledge.

Flying Shape — Once the designer is satisfied with the molded shape, he needs to subject the sail to the forces of the wind. This can be done by integrating it into a load program that exerts various loads on the sail. In addition to the rig information, the sail designer can input information about the fibers and fabric he plans to use. Drawing from a database of known stretch characteristics for different styles of fabric, the sail designer can see how a chosen fabric will stand up to the anticipated loads. The amount and orientation of fibers in a sail will have a tremendous effect on the flying shape of the sail.

These load programs take the design and "flow" air over the surface at predetermined settings. These can include true wind speed (TWS), true wind angle (TWA), leeway, boat speed, and angle of heel. The settings can be changed at random and the result displayed in a





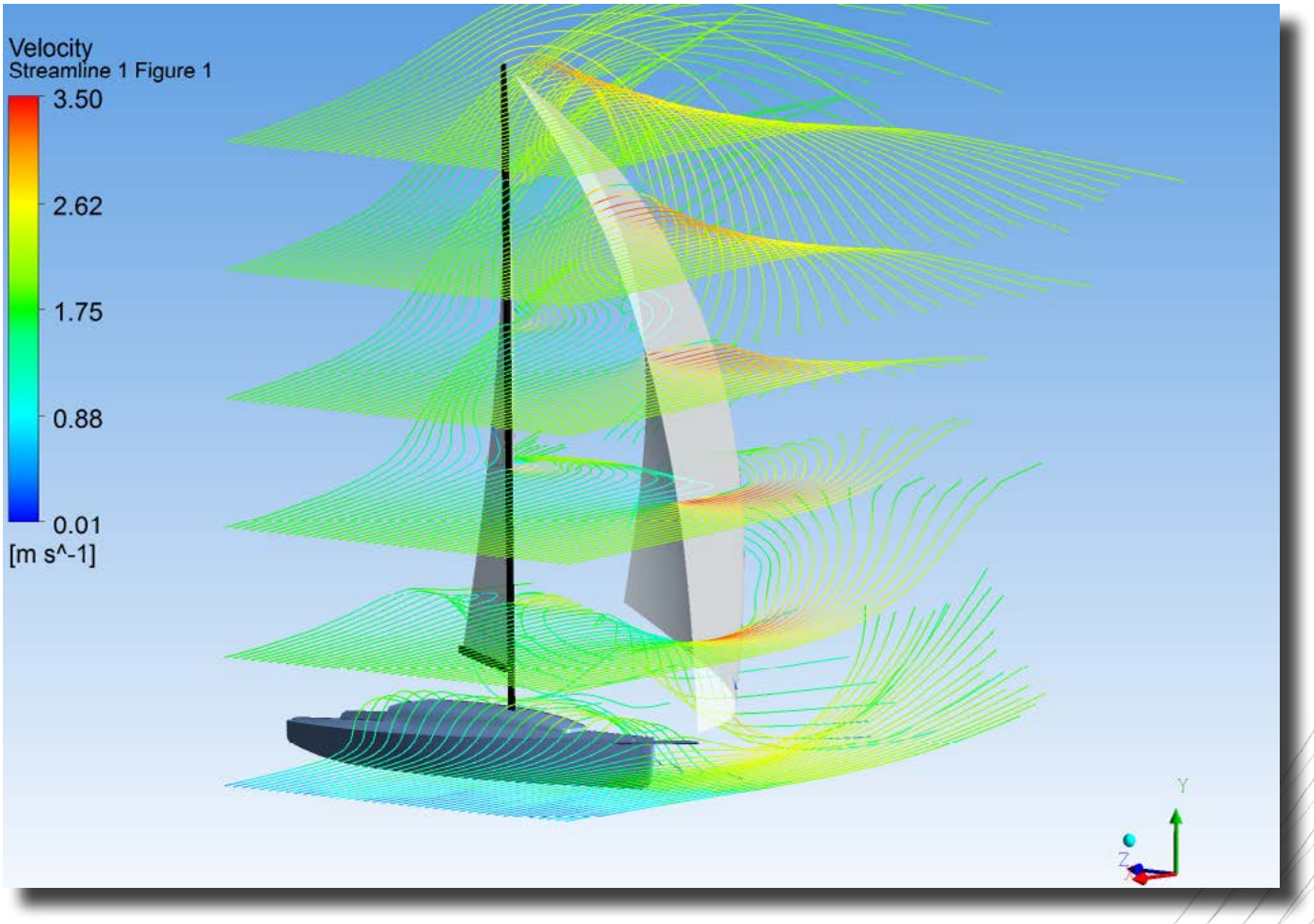
Assessing the various loads in different wind conditions

series of pressure maps that show the various pressures on the sail at any given time. By entering the fabric information, the designer can determine just how effective the fabric choice will be in resisting stretch. This leads the sail designer to the next and most important stage, the analysis.

Step 3 — Analysis

Analysis is basically an extension of the initial load models and determines how the design distorts when it comes under load in the real world, in other words how the molded shape looks when it is flying. With all the relevant data programmed into the computer, the program will now start to compute how much and where the sail will distort when it comes under various loads. This distorted sail shape

is then recreated as a molded shape and the new shape again run through the flow program. This back-and-forth process continues until the sail designer is happy with his design, i.e., when the wind and other forces will not over-tax the fabric, and when any potential distortion can be accommodated by engineering. The designer can also manipulate the sail mechanically and see what effect it has on the loads, and by extension, the shape. This manipulation can be in the form of easing or tightening the backstay, easing or tightening the sheet, or changing a sheet lead position. Modern programs are sensitive enough to respond to even the finest adjustments. Therefore, by careful manipulation and analysis, the sail designer can tweak the design until he is satisfied.



Adding wind to a three dimensional design

This part of the design process may last only a few hours if a similar type of sail has already been designed and built for a previous customer, or it may last a week or more if it's a custom design for a high-stakes project like the America's Cup or Volvo Ocean Race. Once the designer is happy with his creation, his initial involvement with the sail is finished and the process moves on to the next stage.

Part 4 of Where Art and Science Meet will look at The Five Steps to Making Sails. A look at how the design translates into building the sail

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