Blog written by
BRIAN HANCOCK
brian@greatcirclesails.com

MAXIMUM SAIL POWER

CHAPTER 4

A PRIMER ON PANEL LAYOUTS

Different Layouts for Different Fabrics - Part 1

DIFFERENT LAYOUTS FOR DIFFERENT FABRICS

In this chapter we will look at how different kinds of fabrics are used for different applications and different panel layouts. Part 1 will cover early fabric layouts and how fabric engineers started to make different sailcloth for different applications.

Aerodynamic shape and engineering

There are two equally important aspects to sail design: aerodynamic shape and engineering. Aerodynamic shape refers to the curved foil that the sail will present when it is flying under certain conditions. Engineering refers to the various fabrics and fibers that will be used in building this foil and the precise manner in which they will be put together. In fact, these two aspects of sail design go hand in hand since a perfect shape is useless if it distorts when a load comes on the sail. Similarly, an over-engineered sail is equally useless if its shape is not conducive to good performance. This balance between shape and engineering is a delicate one, and the process starts with a careful analysis of the various loads that the sail will undergo when it is being used. Once the sail engineer knows precisely what loads the sail will encounter he can build it accordingly using just enough fiber and fabric to handle the anticipated loads without any unwanted stretch or extra weight.

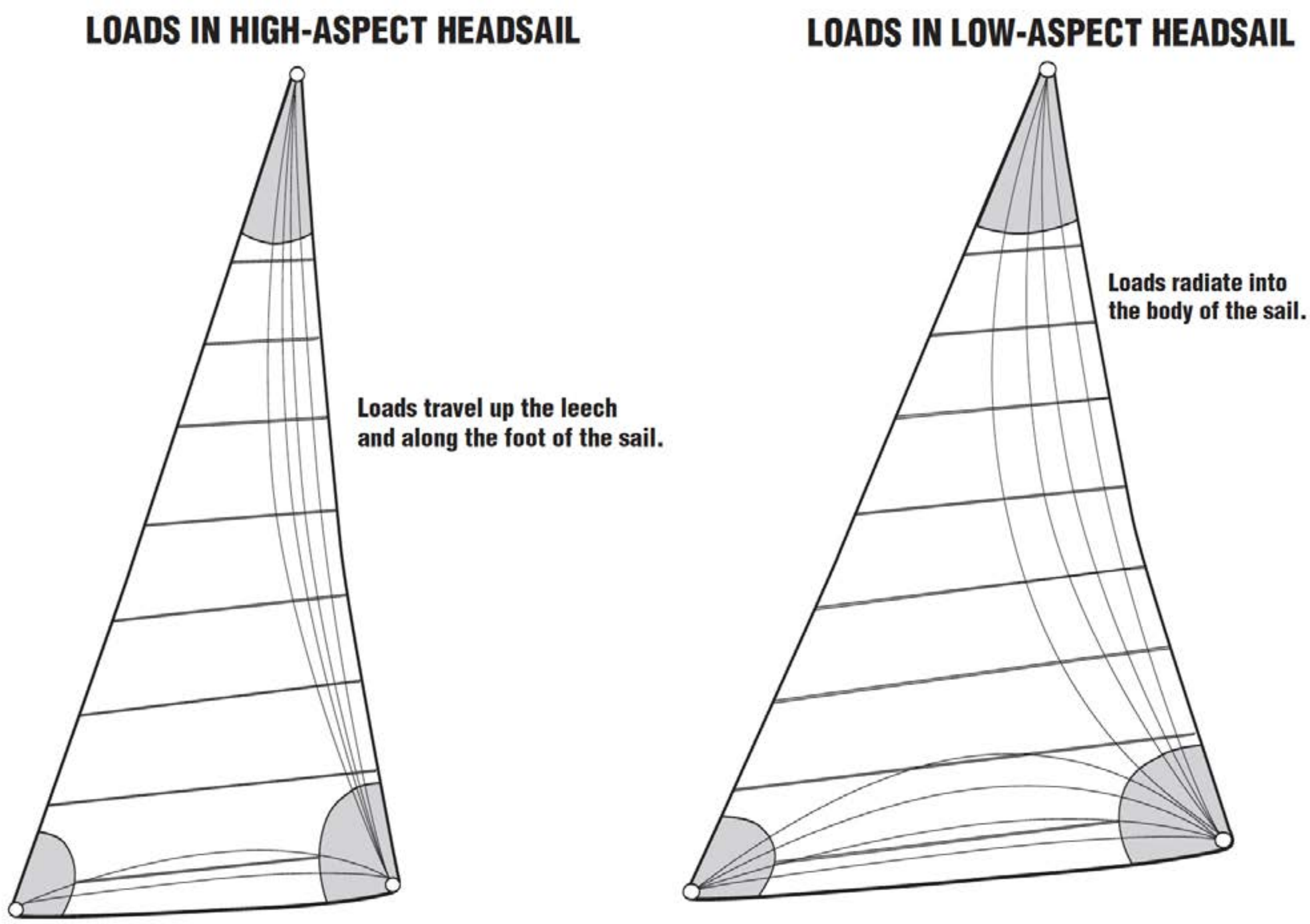
This load analysis has two parts to it. The first is called finite element analysis, in which a sophisticated computer program simulates the sail flying in various wind strengths and angles, and then graphically represents the different loads in the sail. The second involves calculating the exact strength and stretch resistance of each individual fiber and the finished fabric that is to be used in the sail. As discussed in Chapters 2 and 3, a good fabric engineer will know both the tensile strength and yield strength of the various fibers, and will be able to provide the sail designer with this information so that it can be factored into the engineering process. The designer can then take full advantage of the strength and stretch attributes of the sailcloth and incorporate them into his design. The goal is to keep the sail as light as possible, but still strong enough to be usable throughout its designed wind range with- out changing shape. Panel layouts and corner engineering are also an important part of this process, although before we look at this area in more detail, we need to take another look at the critical subject of load analysis.

Finite Element Analysis

Finite element analysis programs came about because of the complex nature of some of the engineering problems faced not only by sail engineers, but by engineers in general. For example, it's fairly easy to calculate how much a steel beam will deflect when it is suspended between two points. It's also fairly easy to calculate the loads a sail will be subjected to under a specific set of conditions. The problem, however, is that the conditions never remain the same for more than an instant. Wind strength, waves, heel angle, air density, and a myriad of other factors come into play. In order for the engineer to calculate how the fibers and fabric will respond to the different conditions, he needs to break the entire problem down into small, solvable problems, and then feed this information into a finite element analysis program that will be able to solve the larger complex problems that result. The small, solvable problems can be expressed as mathematical algorithms that can then be interpolated into the engineering requirements for the more complex problems. Only by knowing the answer to the most basic of equations can the larger engineering problems be solved.

The sail designer starts with some basic information. He has the geometry of the sail, the designed shape and the anticipated wind range for the sail. All this information can be entered into the finite element analysis program, which will then represent the sail graphically on a computer screen. Once he has all this information in place he can begin to manipulate the conditions. He can increase the wind strength and see what result it has on the fabric. He can move the sheet lead position and see how the load paths in the sail change. He can also alter the wind angle and ease the sheet to watch how the loads in the sail will travel along different catenaries. Since a sail is an object that can be infinitely manipulated, and the wind is an infinitely variable element, another job of a sail engineer is to decide which parameters to engineer the sail around. For example, if he is designing a headsail for an America's Cup boat that he knows will only be used on an inshore course for sailing as close to the wind as possible, he would not bother too much about wider wind angles. Instead, he would have the computer program simulate the sail being used within its designed wind range sailing hard on the wind and see what loads the sail encounters. If, on the other hand, he is designing a headsail to be used on an Open 60 sailing in the Southern Ocean he would know that the sail would never be used in a hard-on-the-wind situation. Rather, the sail would be used reaching and running. Therefore, engineering the sail for dead upwind conditions would not make any sense. The same applies to designing a sail for a cruising boat or a smaller one-design boat like a Soling or a Flying Scott. The amount of analysis for these sails will not be as much because the uses are less complex, and the time spent doing the analysis adds to the cost of the sail. But some kind of analysis is still important for creating the best possible all-around sail.

Note that the loads in a sail are also affected by the geometry of a rig, and in particular the aspect ratio or height-to-width ratio of the sail. For example, when



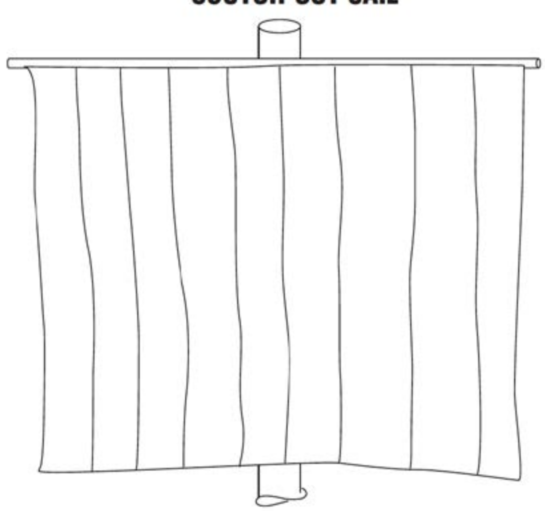
sailing on the wind, a high-aspect sail like a blade jib will have the bulk of the load travel almost directly up the leech of the sail with less stress along the foot. A low-aspect sail like a No. 1 genoa, on the other hand, will have the loads travel more toward the center of the sail rather than concentrated along the leech. It will also experience greater loads along its foot than the high-aspect sail. By knowing where the loads fall and combining this information with the strength and stretch resistance of the individual yarns, the sail designer can begin to develop an overall picture of an optimal panel configuration.

As you will see in future chapters, the art of aligning yarns along specific load catenaries has become a sophisticated process, far more complicated than in the early days when there were only a few ways to configure a panel layout. As noted in Chapter 3 many different styles of fabric are available, and a number of different construction techniques are also available. Fortunately, it's not rocket science, and understanding even a little about how and why sails are built in a particular manner will go a long way toward helping you make the appropriate decisions the next time you are in the market for a new sail.

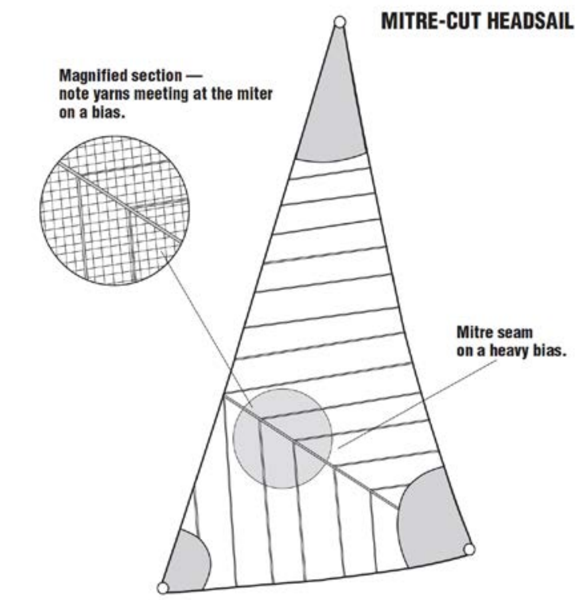
Mitre and Cross-Cut Sails

Before we look at some of the latest sail designs, it's once again important to look to the past. As was the case with sail fabrics and yarns, if we understand how we got to where we are today, we will have some idea of where we might be going. Sail engineering is all about making good use of raw materials, both raw fibers and sailcloth.

SCOTCH-CUT SAIL



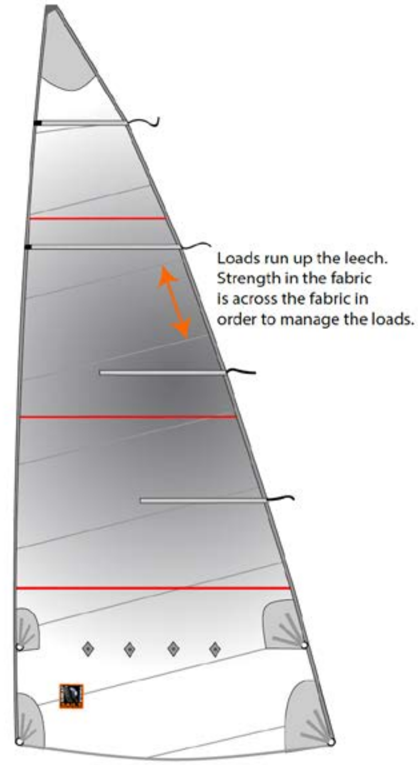
Back in the days of square-riggers and trading schooners all sails were made in much the same way, i.e., with their panels laid parallel to the leech of the sail in what was referred to as a Scotch-cut pattern. This was true for both square sails and triangular headsails, despite the face that they were subjected to markedly different forces. Then in the middle of the last century a company by the name of



Ratsey and Lapthorn Sailmakers, based in Cowes on England's Isle of Wight, realized that fill yarns had less stretch than their warp counterparts, and that this fact could be used to some advantage in terms of sail shape. Specifically, the company discovered that by rotating the fabric 90 degrees, it was suddenly able to achieve a moderate amount of leech control, something that had until that point eluded sailmakers. For mainsails, where two out of three edges are supported by rigid spars, they ran the fabric all the way across the sail from the leech to the luff in what came to be called a cross-cut pattern. For the headsails, which were only sup- ported along the luff by a headstay, they ran the panels perpendicular to the leech, and perpendicular to the foot as well so that both parts of the sail would benefit from the stretch-resistant fill yarns. The panels met in the body of the sail with adjoining panels cut at an angle to both the warp and fill yarns on what was called a heavy bias. Fortunately, the middle of most sails is a low-load area so this bias didn't result in too much distortion, although it could be very difficult to get the sail to look good when there was so much opportunity for stretch. In the old days, when sailmaking was more art than science, sailmakers were often judged by how well they could sight and cut the mitre line.

A Case for Multiple Plies

The fact that the fabric along the luff of sails was overkill was not lost on sail-makers, but until they figured out that fabric could be plied, or made up of multiple layers stacked on top of one another, there was little they could do about it. Sails were engineered for the loads on the leech and the excess fabric strength at the front end (generally in a low load area) got a free ride. When I worked for Hood Sails in the early 1980s we had a lock on the maxi-boat market. Maxi boats back then were 80 feet long, giants for their time, and the sail inventories consisted of five or six headsails of varying sizes and weights, plus a number of other sails like staysails and spinnakers. Some of the boats carried 15 to 20 sails on board each time they left the dock to go racing, which represented a tremendous bulk. It did not make any sense to remove excess weight from the boat in the form of spare tools and unneeded toothbrushes when the bilge was stuffed with heavy, overbuilt sails. When they were wet, which was much of the time, it was even more of a problem.



The way that different fabrics are used to make different kinds of sails will continue in Part 2 of A Primer on Panel Layouts. We will look at radial sails and how building a radial sail is a much more efficient way to engineer a sail.

I hope that you enjoyed this blog. There are many more at my website www.greatcirclesails.com. If you need new sails for your boat just click this box and I will send you a no obligation quote.

BRIAN HANCOCK
Owner Great Circle Sails