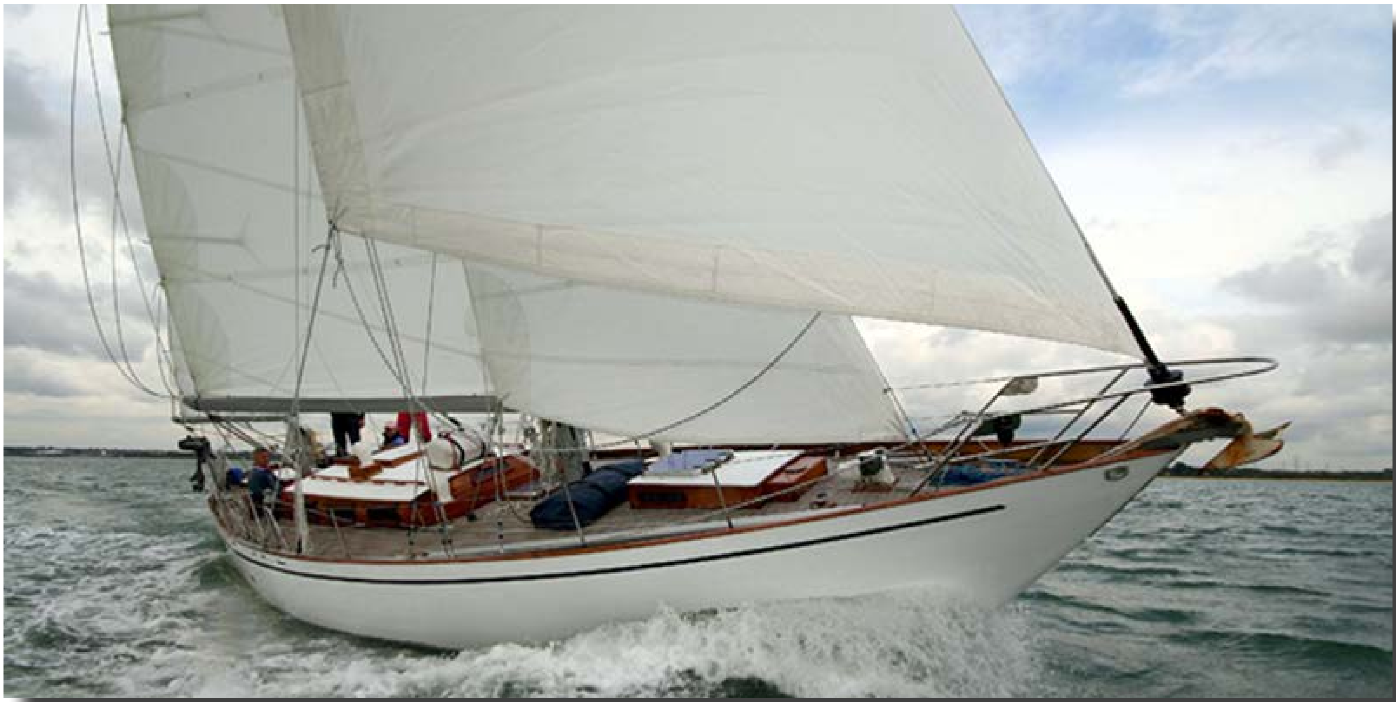
Blog written by
BRIAN HANCOCK
brian@greatcirclesails.com

MAXIMUM SAIL POWER

CHAPTER 3

FROM THREAD TO FINISHED FABRIC

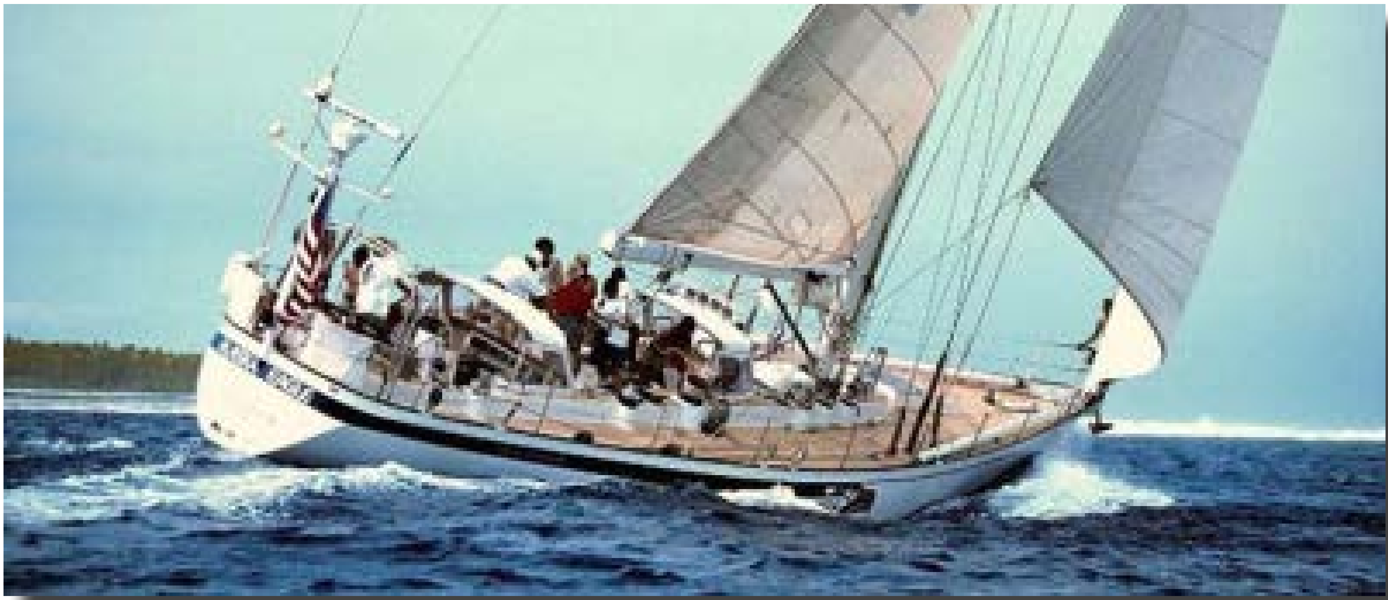
How sailcloth is made - Part 3



CHARACTERISTICS OF GOOD SAILCLOTH

Stable Fabrics at Last

In Part 1&2 of this chapter we looked at the process of making woven dacron and the steps that go into making a fabric that resists bias stretch and holds its shape. The weaving process has come a long way and with this kind of stable sail fabric on the market, the art of sailmaking had at last reached the point where a designed sail shape was not easily distorted, and sail designers could start to experiment with different fabric weights and strengths in an effort to refine their work. Design development is heavily reliant upon hard data, which in turn can only be created from fabrics that are predictable, stable, and uniform. Even the earliest Dacron fabrics were better than their predecessors and were used successfully on both cruising boats and high-performance racing boats like those in such demanding events as the America's Cup and Whitbread Round the World Race (now the Volvo Ocean Race). They were tried and tested under some of the harshest conditions, and to this day many sailors swear by their basic woven Dacron sails. There is something about a product that has stood the test of time that instills confidence. On the other hand, while the status quo might be good for most sailors, a few always demand and expect more, and since the early days of Dacron a lot has happened.



My first around-the-world race was aboard Alaska Eagle and we carried dacron sails

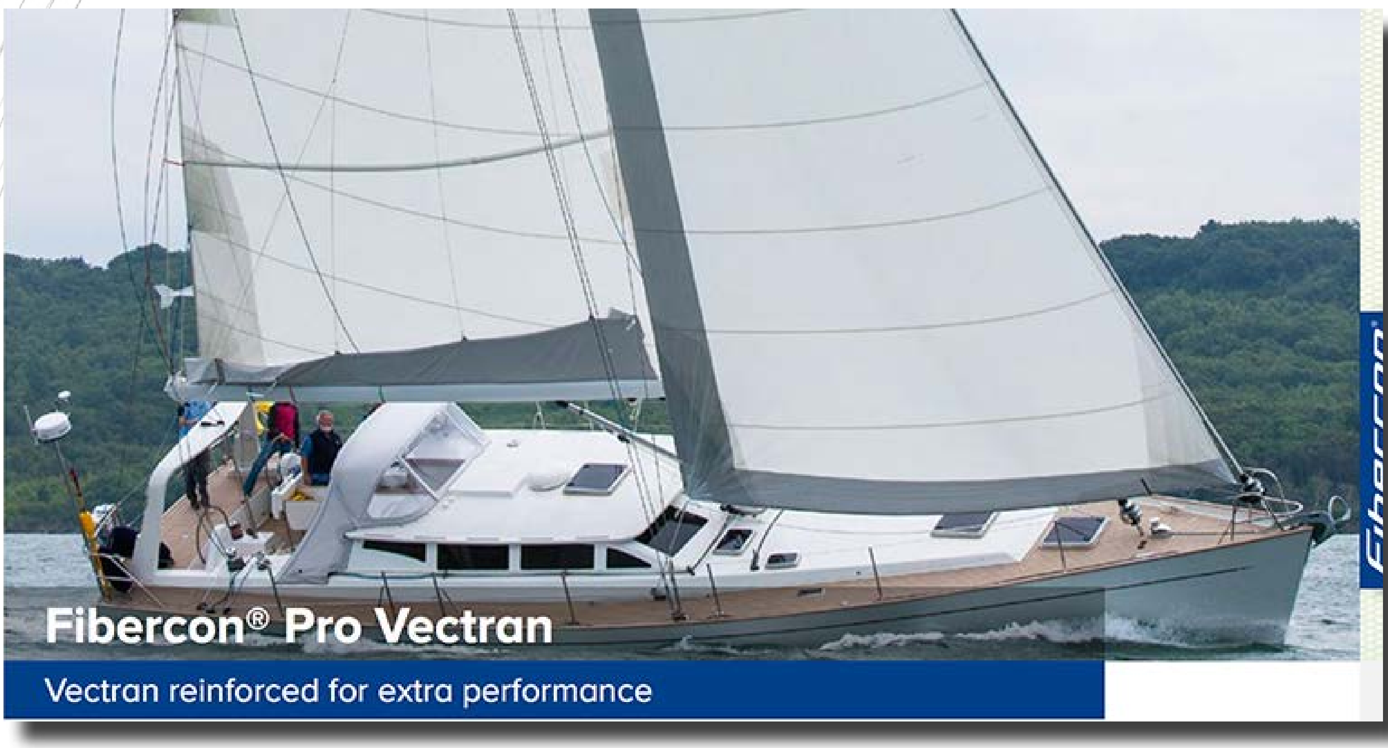
An Effort to Improve Dacron

Despite the fabric engineers' best intentions, for example, after a while all those fillers and finishes added to woven sailcloth begin to break down, and what starts off as crisp, low-stretch fabric becomes a softer, more easily manipulated sailcloth that begins to stretch and distort the sail shape. Therefore alternative means of creating a tight weave were sought.

In the late ‘70s and early ‘80s Hood Sails believed it had solved the problem by producing its fabric in 24-inch-wide panels, rather than the 54-inch panels used by other fabric makers. With less distance upon which to exert pressure, it was reasoned, the beater would be able to create a tighter weave. There was probably some truth to this line of thought, and narrow-panel Hood sails were seen all over the world. In time, however, they were replaced by newer technologies, since among other things the added cost of sewing twice as many seams pushed the price up for very little commensurate gain.

Sailmakers also discovered that if the warp yarns were made much heavier than the fill yarns and then were pulled through the loom with a lot of tension the fill yarns would actually bend, leaving the warp yarns with much less crimp. This was especially helpful in terms of radial-paneled sails, i.e., sails made of panels radiating from the corners of the sail as opposed to the parallel panels in a cross-cut sail. Unfortunately, you could not have a fabric that was completely dominated by the warp to the exclusion of the fill since the result would be a lot of bias stretch. In order to increase the overall strength of the fabric, larger fill yarns had to be introduced, but they did not respond the same way as the light yarns since they were not as bendable, and the result was once again crimp back in the warp. There had to be a better way.

Fabric makers knew that small-denier yarns could be woven tighter than their larger-denier counterparts to create a more stable fabric since the thin fibers were more responsive to the pressure exerted by the beater, as well as the heat setting. But these lighter fabrics were not much use on larger boats, so fabric makers had to come up with a way of increasing the strength of the fabric without losing the positive attributes of small denier weaving. With this in mind they started to weave fabrics with both a light, tightly woven base and additional heavier yarns in the warp and fill direction. The light base provided great bias stability, while the heavier yarns added strength. Fabric makers also discovered that they could introduce different kinds of fibers like Vectran into the weave thereby increasing the overall strength and stretch resistance of the fabric that much more. And there was another great side benefit. The light base provided high tear resistance. Despite the added work (read expense) of incorporating different threads, the results represented a tremendous leap forward.



Contender Sailcloth makes a great fabric that incorporates Vectran threads for additional strength

Other Characteristics of Good Sailcloth

To further emphasize why fabric manufacturing is a complex process, it's important to realize that in addition to creating a material that does not stretch, does not distort under load, is easy to handle, and is rugged enough to withstand gale-force winds as well as fly in light zephyrs, fabric makers need to consider a number of other points, some of which aren't quite so obvious as the factors discussed thus far, but which can be just as important to a sail's performance in the long run.

Fabric Strength

As is the case with fibers and yarns, there are two important strength considerations when it comes to fabric. The first is the breaking, or tensile strength, and the second is yield strength. Breaking strength is obvious. Nobody wants their sails to break apart and if engineers know the point at which a certain fabric fails under tension, they can design accordingly. Yield strength, on the other hand, is a trickier number, although no less important since it tells the sailmaker at which point the fabric, and by extension the sail will start to distort, thereby compromising its aerodynamic integrity. If you use your sails in too much wind, for example, it's unlikely they will blow up unless the fabric is old and UV damaged. What will happen, however, is that the shape will distort and then remain so with the result that, for cutting-edge racers in particular, the sail will be as useless as if it had blown apart. A conscientious sailmaker will let you know the wind range in which any sail can be flown, and you would do well to adhere to their recommendations.

Tear Strength

Another problem with adding fillers and finishes to a woven fabric is that the fabric becomes brittle, making it more susceptible to ripping. Specifically, by adding resin to the yarns they become brittle and tend to break one at a time like a chain of falling dominos, with the result that the tear strength goes down accordingly. If, on the other hand, there is little or no resin the fibers are able to move freely and tend to gather and bunch as the fabric begins to rip. To see this, try tearing a loosely woven material like a dish towel, or stick a spike through the fabric and pull down on it. Instead of simply breaking you will see that the individual yarns tend to slide away from the rip transferring some of the load onto a number of neighboring yarns, effectively forcing them to share the load.

Tear strength, not surprisingly, is important to the overall life of the fabric, and by extension, the life of the sail. Sailboats offer a harsh environment for fabrics, with sharp edges and uncovered fasteners waiting to snag an unsuspecting sail. If the fabric is resistant to tearing, the life of the sail is greatly increased. There are some ways to improve a fabric's resistance to tearing, i.e., a looser weave or less filler, but of course this also means that the fabric is less effective at maintaining its designed shaper under load. As with many things in the fabric-making business, it becomes a compromise between competing interests.

Abrasion Resistance

This is not a huge problem for woven Dacron sails, but does become a con- cern with some of the more exotic fibers. In some cases, adding resin to the finish can decrease the abrasion resistance of the fabric, while at other times it adds to it. For example, if the body of the sail is rubbing against something like a shroud or stanchion, the resin can add a layer of protection around the sail's many individual fibers. On the other hand, since the resin makes the fabric more brittle, it is more susceptible to abrasion if an edge of the sail or a fold is being affected. Reefing a mainsail, for example, offers many edges and many points for abrasion.

Ultraviolet Degradation

The real problem with all kinds of fibers and fabric is the sun. Sooner or later UV light penetrates the fabric and breaks it down. Fortunately, fabric makers can do a lot to protect the yarns either by adding a UV inhibitor to the individual yarns before they are used to make the fabric, or by dipping the finished panels in a solution that coats the fabric with UV protection. The UV protection itself contains titanium dioxide, which provides whiteness and opacity to the fabric. It also has a very high refractive index—surpassed only by a diamond — and it's this refraction that protects the yarns from the UV rays. The more effective way is to treat the yarns individually, since surface UV coatings are thin and can wear off over time, but it is also more expensive.

Water Absorption

Not only does water attract dirt, which can lead to mildew and other discoloration, it also adds weight. Some fabrics wick and retain water more easily than others, and in a wet environment this can be very important. New fabrics that have the resin finish still perfectly intact repel water much better than old fabric that has had some of the resin break down. There is no use manufacturing a fabric to exacting specifications only to have it increase in weight by 20 percent after lying in the bilge. Many sailmakers are beginning to add water repellents to fabric to minimize water absorption. These water repellents can also be added to old sails to improve their water resistance.

Fabric Smoothness

The friction of the wind passing over the sailcloth adds drag, so it's important to keep the fabrics as smooth and friction free as possible. The resins that coat the fabric present a smooth surface, especially on fabrics made from smaller denier fibers.

Factors That Affect the Price of Dacron Sailcloth

In order to provide a yardstick by which fabrics can be compared, fabric makers rate the performance of different sailcloths by dividing the modulus of a fabric by its weight to determine a number called the "specific modulus." In most cases fabric makers are striving for a high modulus/low weight fabric, in which case they might incorporate some exotic yarns into a fabric to give it more strength. On the other hand, there are some occasions where durability needs outweigh performance, and in these cases a high modulus/low weight combination will not be the driving factor when designing the fabric. For example if you were choosing a fabric for a Dacron No. 1 racing genoa for your C&C 42 you might consider using one that has some more exotic yarns like Vectran incorporated into the weave which would give the sail the performance edge you were looking for while keeping the overall weight of the sail down to around 5.5 ounces. On the other hand if you wanted a No. 1 genoa for cruising to Bermuda you might choose an 8-ounce balanced Dacron that would be heavier, but also have the strength and durability you need for an offshore passage. Since Dacron was first introduced in the mid-1950s, there has been a lot of development in both the fiber and the fabric. Unfortunately, some of the development is not discernible by casual observation, and the difference between a top-quality Dacron fabric that will perform well for a number of years, and a fabric that will break down and distort quickly is not easy to see.

Four primary factors affect the quality and cost of Dacron sailcloth:

1. Yarn quality — The quality of the yarns that fabric makers use to manufacture sailcloth vary in terms of tenacity, modulus, creep, and weaving quality. A high-tenacity, high-modulus yarn that is produced specifically for weaving is the most desirable. It is also the most expensive.

2. Yarn content — Most fabrics are either balanced or fill-oriented, and the ratio of warp to fill yarns should correspond to the aspect ratio of the sail, i.e., the ratio of the length of the luff to the length of the foot. High-aspect sails like blade jibs, for example, should be manufactured from fill-oriented fabrics, while low-aspect sails like genoas should be manufactured from balanced fabrics.

3. Tightness of the weave — The tightness of the weave varies for a number of reasons, including the size of the yarns used and the amount those yarns shrink. The smaller the denier of the yarn used, the tighter the weave, and the more the yarn shrinks when heated, the tighter the weave. A tighter weave will call for less resin to be used to stabilize the fabric. Manufacturing fabric using smaller denier yarns is more expensive. It requires more shuttle passes and takes more time to weave than a larger denier fabric.

4. Types of finishes — Highly resonated fabrics rely on the resin for stability, rather than the integrity of the weave. Those fabrics that have been treated with excessive resins are much stiffer to handle and tend to lose their performance edge once the resins break down. The quality and quantity of the resin greatly affects the overall cost and quality of the fabric.

Taking the above factors into account, the price of woven fabrics can vary greatly. You need to be aware of these differences if you are considering Dacron fabric for your own boat. You get what you pay for.

A Final Word About Woven Fabrics

Once the fabric maker has produced the sailcloth, it goes to the sailmaker to be turned into sails. Sailmakers will tell you that they prefer stiff, flat sailcloth when they are designing and building sails since a rigid surface is easier to cut and sew. Woven fabrics with little or no finish, while nice for the sailor to handle, are difficult for the sailmaker to use because the soft fabric moves around too much and seams tend to pucker while sewing. As with everything in sails, sailing, and sailmaking, it's a delicate balance among differing objectives. Trends and fads have their place in the business and they pull and tug at convention. In the end the products improve and the sails last longer.

Note: In Part 4 of From "Thread to Finished Fabric" we will look at laminates and how they change the engineering of the fabric and improve the performance of the 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