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MAXIMUM SAIL POWER

CHAPTER 3
FROM THREAD TO FINISHED FABRIC
How sailcloth is made - Part 4

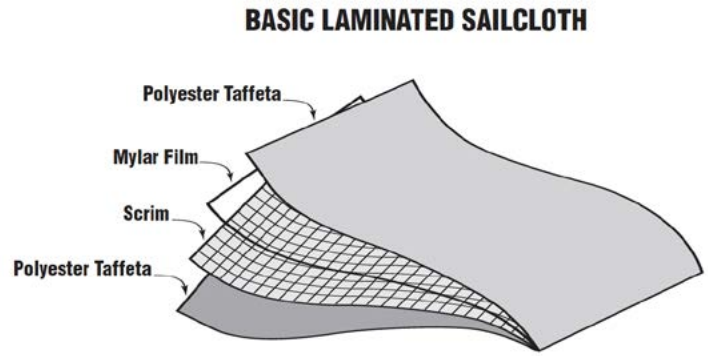
LAMINATED FABRICS

While woven fabrics have stood the test of time, sailmakers are continually looking for new ways to build sails, and in particular for ways to graduate the weight of fabric throughout the sail since the different parts of a sail experience markedly different loads. For example, there is little need to have heavy fabric along the luff or in the body of the sail since these areas are subjected to very little loading. The leech, on the other hand, is an area in which a sail designer needs to be sure to place a fabric with both high modulus and tensile strength. Unfortunately, when woven fabrics were used to build cross-cut sails, i.e., sails built up of horizontal panels of sailcloth, the fabric used for the leech ran all the way across the sail to the luff making any kind of graduation impossible. For a while, vertically paneled sails seemed to hold the answer, and warp-orientated fabrics were manufactured for this purpose. But woven Dacron is not really suitable for building vertical or radial sails because of the crimp in the warp yarns. Warp-oriented nylon, which is used principally for spinnakers, works because the fibers are so small there is virtually no crimp in the weave, and indeed a little fabric give in a spinnaker is a good thing. But for working sails there had to be a better way. Ultimately, laminated fabrics and sails proved to be the answer.

In some ways laminated fabric is similar to woven fabric in that it comes in bolts of cloth from which panels are cut and assembled to make a sail. It differs markedly, however, in the way the various fibers and other materials are joined together. Note that laminated fabrics and sails, although they involve similar technologies to molded sails, are quite different, as will be discussed in Chapter 5. Among other things, with molding technologies the whole sail is laminated at once so that there is no need for pre-made bolts of cloth from a fabric maker. In fact there is an ongoing debate surrounding these two methods and which permits the most efficient bond between the various layers. Companies like North Sails, which makes molded sails using 3DL technology, or Doyle Sails, which uses D4, believe they have the best method. Manufacturers of conventional laminated fabric, however, claim that they are able to bring more pressure to bear on their laminate and therefore are able to use less adhesive, resulting in a stronger, lighter fabric.

Parts of a Laminate

As soon as two layers of fabric, fibers, or film are bonded together it becomes a laminate. It does not matter what the layers are made of. Fabric makers have experimented with all sorts of different layers to create sailcloth, but in the end a simple two-layer laminate often works best, with the two basic layers being comprised of load-bearing yarns and a substrate made from a film like Mylar. The yarns provide the strength and stretch resistance along load lines, while the film is there to provide bias, or off-threadline stability.



Combining additional layers allows fabric makers to be more comprehensive in terms of creating a fabric that will handle numerous loads running in various directions. Note that an additional advantage of laminating technology is that since the load-bearing fibers do not need to be tightly woven, they can be laid into the fabric as a "scrim," in other words a loose knit of fibers that, because they are not woven, do not have any crimp in them. The yarns themselves can also be created as flat ribbons as opposed to twisted yarns, so that there will be no tendency for them to untwist when the load comes on them, thereby reducing any potential stretch further still.

Some Background

Laminated sails were first introduced in the late 1970s, making their debut in the high-performance arena of the America's Cup, and over time they have trickled down to racers and even cruisers at local yacht clubs. The secret behind laminated sails is the adhesive that binds the woven fibers to the extruded substrate or film, since without an adhesive to hold the two together there is no point in even attempting to marry them. Fortunately, chemical engineers have developed adhesives and techniques that make it possible to securely bond the layers while allowing the finished product to remain supple enough to withstand the inevitable stretching and distortion a normal sail endures.

The original laminates were used to make cross-cut sails, but it soon became obvious that a better use would be to make radial sails since there were no restrictions on how the base fabric had to be created. Since it was not necessary to weave the base fabric, there was no problem with having the fabric be fill-orientated to be stretch resistant. Some laminates are actually made with a woven base rather than a scrim, but because the diagonal stretch is taken up by the film, a tight weave is not necessary and therefore there are no problems with crimp. Again, with this technology you can mix and match fibers, yarns sizes, and the number of plies almost at will, all to create a custom fabric for a specific purpose.

The Laminating Process

The basic lamination process is a relatively simple one, although there are many variables. First, a thin film of adhesive is spread on a Mylar film. Then the Mylar and the base fabric, be it a scrim or a woven fabric, are passed between heated rollers that both set off the adhesive and force the adhesive into the fibers. If the fabric calls for more than two layers, the process is repeated until the fabric is completed. In theory, this may sound simple enough, but in practice the variables are many. The fabric engineer needs to consider the following points:

1. The choice of adhesive (a closely guarded secret).
2. The amount of adhesive (less adhesive makes for lighter sails).
3. The temperature and speed of the pass.
4. The pressure exerted on the fabric.

In general terms, more pressure brought to bear on the fabric will require less adhesive. When considering the weight of the glue, this becomes an important consideration as the sail designer tries to minimize weight aloft. In the early days there were many cases — some very high profile — of sails delaminating. Today, however, the process has been refined to a point where there is an almost 100-percent success rate with laminated sails. I have sailed around the world on more than one occasion with laminated sails and have them on my own boat. Not a single sail has delaminated.

The Magic of Films

As long ago as the late 1960s, the problems associated with bias stretch led sailmakers to try to incorporate Mylar films in their sails. The reason for this is that, although Mylar and polyester are chemically similar, the way in which they are extruded makes all the difference in terms of their performance characteristics. Specifically, while polyester yarns are extruded as thin filaments with their molecules aligned in a single direction, Mylar is extruded as a film or sheet with the molecules oriented equally in all directions. As a result its resistance to stretch is the same both along and across the panel, and more importantly, on the diagonal. At last there was something that would resist stretch on the bias and sailmakers leapt to build sails using just the film and no fiber. Unfortunately, they encountered a number of problems, not the least of which was that with film-only sails there was no way to control and manipulate the shape of the sail since it is by tightening control lines like the halyard and pulling on a woven sail's bias that you are able to move its shape. Film sails, on the other hand, are not so easily manipulated — turns out that a certain amount of bias stretch is good for the sail after all! There were other problems as well. For example, the sails tore easily without any cross yarns to arrest a rip, and when the sails were sewn together, each needle hole became a potential weak spot. In short, sailmakers could not use the film without the fiber.

The mylar film is clearly visible in this Carbon Twaron sail

It was with the development of new glues to bond the two together that a whole new world suddenly opened up to fabric engineers, making laminated sails not only practical, but eminently desirable. Afterward, as noted above, laminated sails quickly became a part of everyday sail technology, as increasingly sophisticated ways of layering film and fibers were developed.

A Closer Look at Film Choices

Since Mylar was first introduced into sailmaking there has been a search to improve upon it, but without much success, especially when compared with the gains made in other areas of sailmaking like design and yarn technology. New films include those made of Vectra, Tedlar, and PEN, all of which have significant drawbacks in terms of sail construction. Vectra, for example, is extruded using a process similar to that of Mylar and has the same high-modulus qualities as the sailcloth.

This Swan with tri-radial laminated sails

But tests have shown that while Vectra has the strength to carry the loads on a sail without fiber reinforcement, it has a low impact resistance and shatters easily when used in sails. There have been some attempts to double Vectra up with Mylar to minimize its negative qualities, but the added weight and expense are unacceptable.

Tedlar has also been used in some sailcloth applications where it exhibited excellent abrasion and UV resistance. But it is heavier than Mylar, absorbs slight amounts of water and tends to creep over time. The most important breakthrough in film was when Pentex was used to make PEN film. PEN film, which is an extruded version of the Pentex fiber, is actually stronger than Mylar, but tends to be brittle, less resistant to abuse, and prone to shrinkage, which distorts the aerodynamic shape of the sails in which it is used.

Ultimately, the biggest breakthroughs in film have not been in strength or stretch resistance but in the ability to combine it with UV inhibitors. These UV inhibitors protect light sensitive yarns that are paired up with the Mylar from the sun's harmful rays, thereby extending the overall life of the fabric. They use the same titanium dioxide in the film as they use to coat the fibers.

What About Shrinkage?

Shrinkage, as alluded to in the context of PEN film, is a definite problem with laminated fabrics since it distorts sail shape just as badly as stretch. In the case of film, the material itself does not get any smaller, but when a sail is folded into a bag, it gets scrunched up in such a way that it's impossible to spread it out flat again so that the total area becomes less. To illustrate, take a piece of paper, lay it out flat on a table and measure it lengthwise and diagonally. Now take that same piece of paper, scrunch it up into a ball, smooth it out, and lay it back down on the table and measure it again. You will find that it is impossible to get the fabric to lie out smoothly enough to reach its original size since the bending and folding creases the paper, and those creases are difficult, if not impossible to remove from the sheet. The same thing happens with film. Once it has been scrunched up it never quite recovers. Light fabrics are more susceptible to shrinkage than heavier ones because of the thickness of the film. The bad news is that the problem is not likely to be resolved anytime soon.

Note: In Part 5 of From "Thread to Finished Fabric" we will continue to look at laminates and how they change the engineering of the fabric and improve the performance of the sail.

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