How Sails are Designed and Made,

And How the KSL 505 Spinnaker Was Designed

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As many readers will already know, Steve and Barb Yates, Sue Fraser, and I, have owned and operated Kingston Sail Loft (KSL) since 1st February 2024. One of my goals with KSL was to make fast, world class, affordable racing sails available to my Canadian 505 sailor friends. I know what it costs to purchase 505 sails from leading sailmakers and pay exchange, duty, and taxes on them. We also hope to do the same with Albacores and a few other classes.

There are many of us in the 505 class who have been racing these fabulous boats for a rather long time. The older 505 sailors among us can remember the days of un-cored polyester hulls, before carbon fibre, before Kevlar, before cored construction, before epoxy, before ball bearing blocks and before low stretch lines.

Clearly the technology we leverage in our 505 sailing has changed over time.

Our sail technology has also changed over time. Some of those sail technology changes are obvious, many 505 sailors now use mainsails and jibs with hi-tech laminate cloths, and some used North 3DL sails when they were available. The 505 class started in 1954 using the stretchy fabrics that were available in the mid 1950s, but adopted better sail cloth whenever it was available. Laminate fabrics, Kevlar, Aramid, 3DL, coated nylon ripstop, etc. were all adopted when they proved to be better than the previous sail cloth technology.

What may be less obvious than the changes in fabrics is that the way sails are designed and made has also changed greatly.

Fifty, forty, and thirty years ago, most sails were made with crosscut panels.

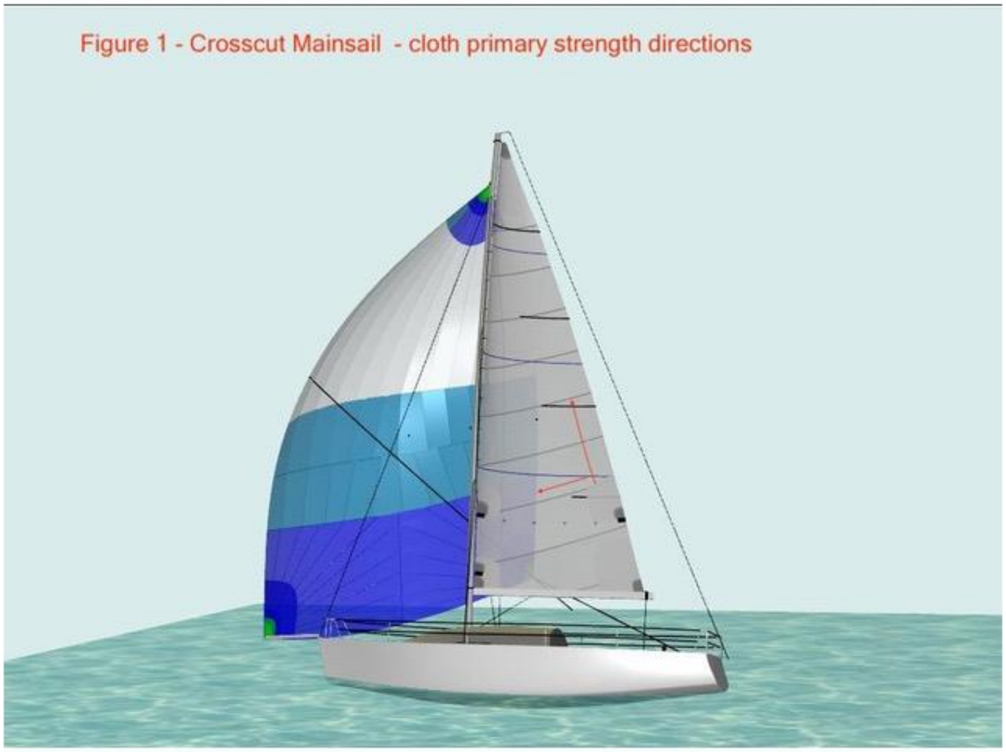

Figure 1: A typical crosscut panel layout on a mainsail. Image from a Keven Piper article

An experienced sailmaker would rely on that experience to lay out the cloth panels on the loft floor with the weft (aka fill) threads aligned with the leech of the sail, and judge how much seam taper (aka broadseaming) was appropriate for each seam. Additional shape would be created with luff curve, though mast bend takes up some of the luff curve on a mainsail, and forestay sag adds shape in the front of a headsail. At every seam one panel edge would be straight and the other curved to introduce some shape to the sail. The major loads on a mainsail are up the leech, and crosscut panel layouts aligned those loads with the weft threads in the cloth.

Once the sailmaker had a sail they liked and wanted to make more of, they could make Mylar templates with the seam curves marked with a tape like masking tape. Dacron cloth, or Nylon ripstop for spinnakers, would be unrolled over the templates and the curved seam marked with pen or pencil by pushing through the cloth against the edge of the tape. Panels would be cut out by hand with scissors, then stuck together with double sided sticky tape, and the seams sewn. This was an imprecise process, as the pen/pencil lines and hand cutting might result in panels that are not quite identical. The resulting sails might not be quite identical.

Patches and reinforcements would be cut out and sewn on. Then the sailmaker would lay a batten on each edge and draw a curve they thought was good, trim the cloth to that curve and finish that edge.

Sail design has changed since then. Sails are now designed using sophisticated computer software – try searching the web for “sail design software”. The better design packages – our designer uses the Azure design software -- allow the designer to create a “3d wire” shape, fair it in all directions, show the effects of mast bend at different wind strengths (for a mainsail) or luff sag (for a headsail), consider load on the mast and sail cloth, check volume distribution, and optimize that shape so it will effectively handle different wind strengths, then decide on a panel layout and have cut files created for a cutter/plotter table that will laser cut all panels, reinforcements, patches, etc. and mark all registration marks. The software will also work to nest panels, minimizing cloth wastage.

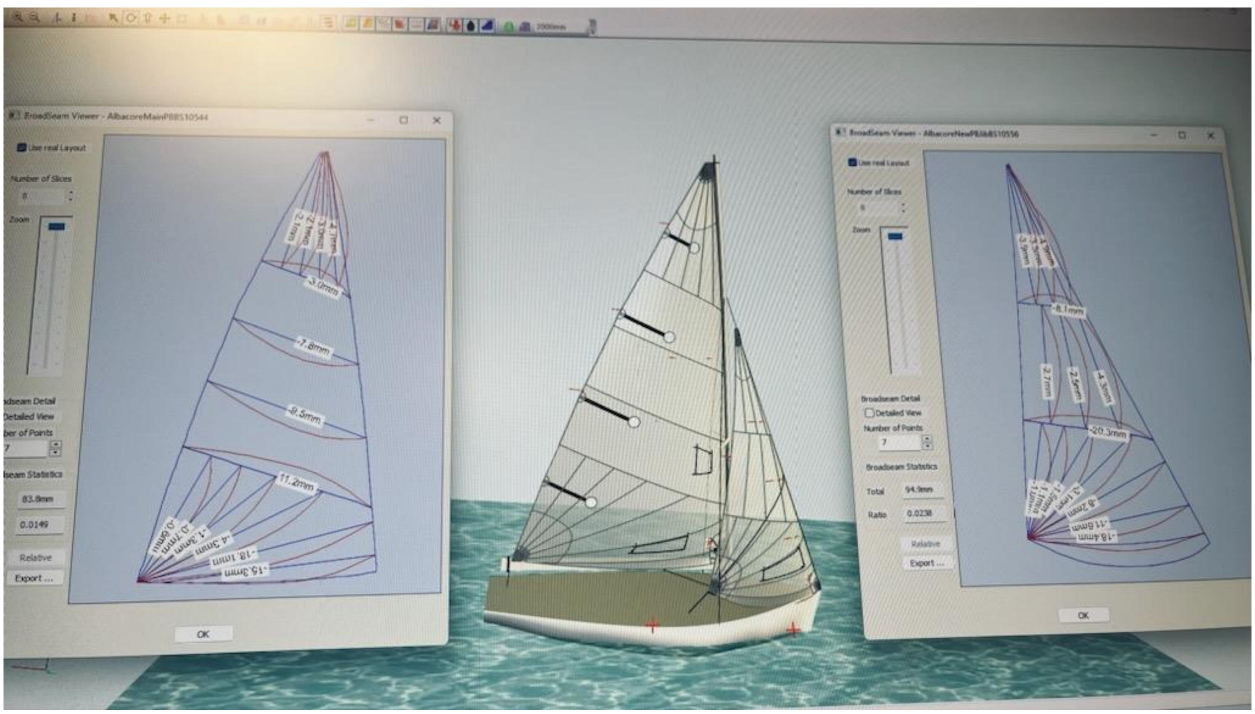

Figure 2: The Azure Sail Design Software Showing the Resulting Shape at Each Seam. These are the KSL Albacore sails being designed. Image from Keven Piper

The computer software calculates the seam taper for each edge of each panel (both edges are curved) and that is what the cutter/plotter produces. Registration marks to ensure correct alignment are printed on the panels, and where any reinforcements are to be placed is also marked. So are the edges of the sail; no more using a batten to draw a fair curve by eye. The tolerances on the cutter/plotter are such that panels will not vary batch to batch over time. The resulting sails are essentially identical. Sail cloth panels are stuck together with double sided sticky tape (this part has not changed), but the registration marks help ensure proper panel alignment, and the sail is assembled and sewn.

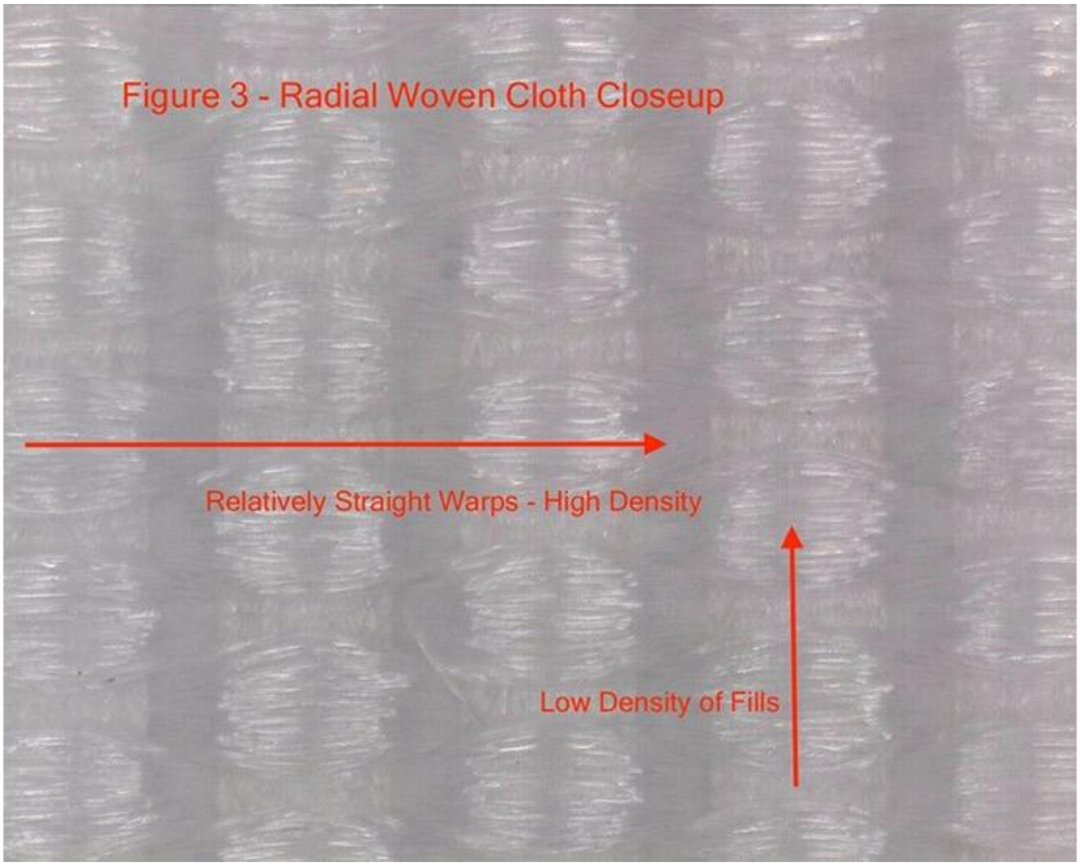

Figure 3: Warp and Weft/Fill. Unattributed; don't remember where I found this image.

If the designer intends to use a warp-oriented cloth, they can choose a radial panel layout. This will better align the loads placed on the sail with the stronger warp thread line on the cloth, and reduce bias loads on the cloth.

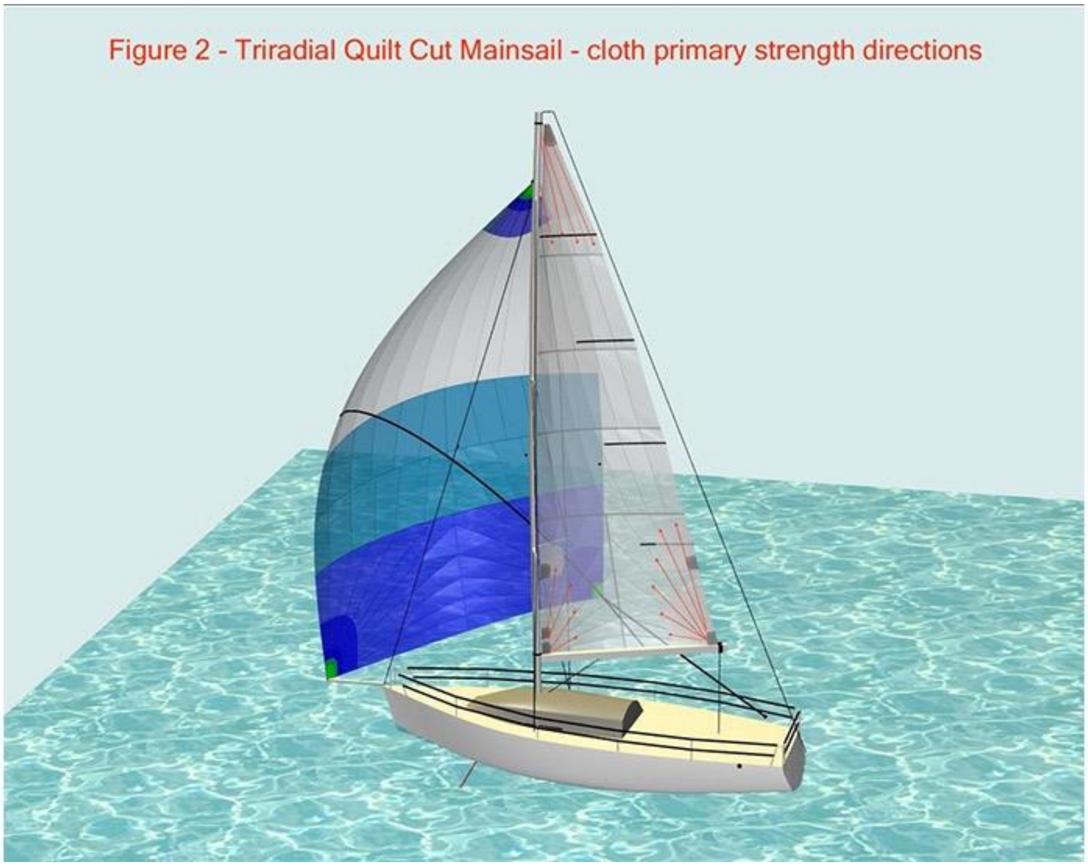

Figure 4: A Radial Quilt Cut Panel Layout on a Mainsail. No more crosscut panels. Image from a Keven Piper article.

Spinnakers are an interesting design problem as they are free flying and no edge of the spinnaker is attached to a spar. The sail is controlled by the sheets and halyard (and spinnaker pole) attached to each of the three corners.

The design software helps the designer develop a smooth fair shape. The software also looks at the load placed on each element of the sail, and shows areas that are more heavily loaded.

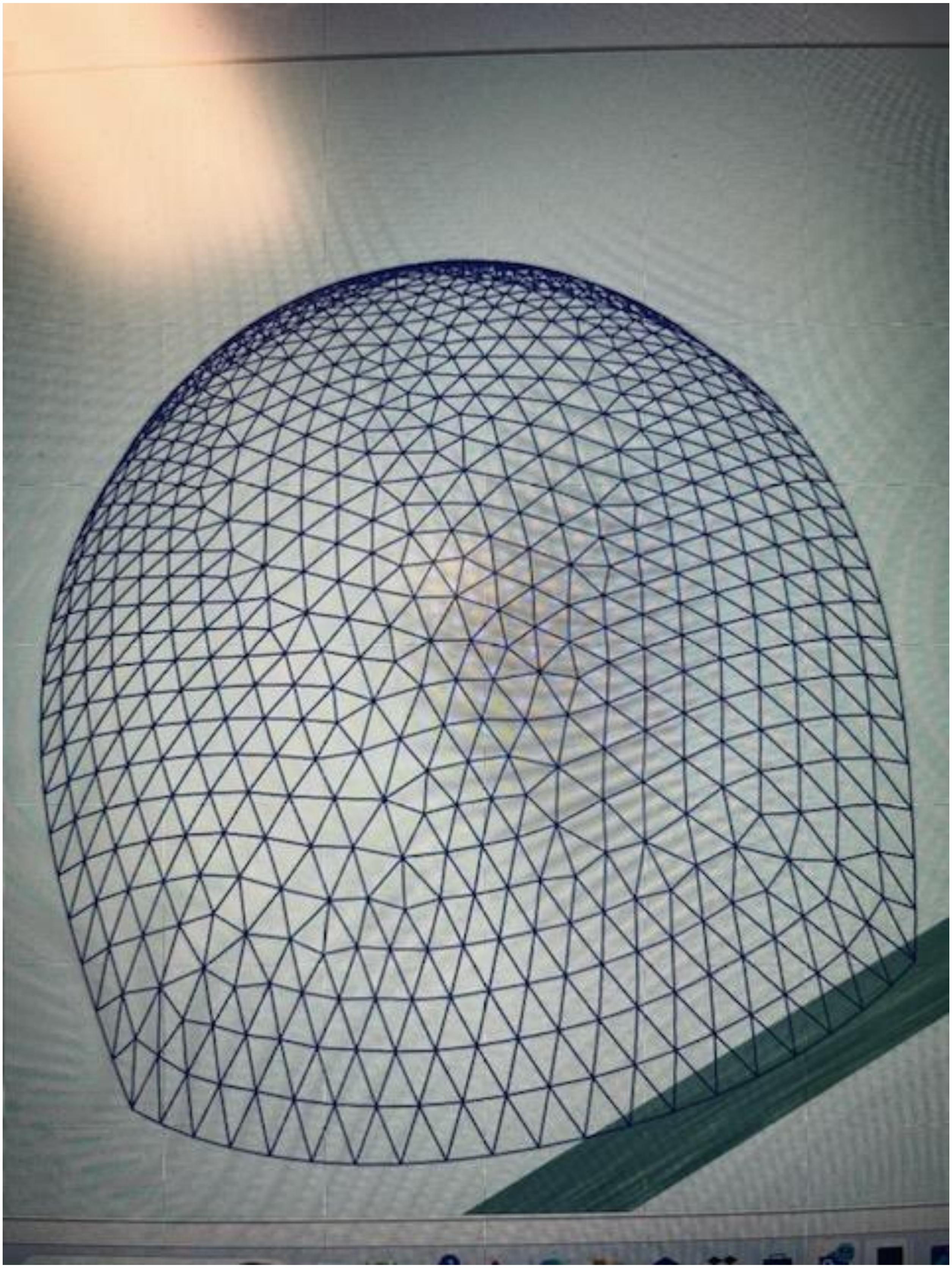

Figure 5: A "mesh" showing loads placed on elements of the spinnaker. Image from Keven Piper; this is generated by the Azure design software.

If the designer chooses a warp-oriented spinnaker cloth, they can select a radial panel layout that aligns the warp threads with the loads on the sail. Crosscut panels will have some of the load on the bias, off thread lines.

The designer will consider class measurement rules and will seek to design the fastest spinnaker that meets those rules. The designer will consider the wind strengths the spinnaker will be used in. With 505s, we reach downwind in very light air, keeping the pole forward and the boat moving to generate more apparent wind. There is a narrow wind range when we sail dead downwind with the pole back, but as the breeze builds we quickly transition to pole forward reaching – wire running – as the resulting greater speed more than makes up for the greater distance sailed. Some 505 sailmakers offer two spinnaker designs, one for the normal pole forward mode, known as VMG (velocity made good) mode, and another for the pole back DDW (dead downwind) mode. The VMG spinnaker is typically flatter with less horizontal curvature near the leeches, and straighter vertical camber profile as well. The pole back DDW spinnaker tends to be fuller and generates a bit more power for going low with the pole back, but has more drag when trying to reach with the pole forward. Many 505 teams use just a VMG kite as it is still OK in that narrow DDW wind range whereas the DDW running spinnakers are not fast in pole forward conditions.

There may be trade-offs between a smooth fair spinnaker shape and adding area, such as in the shoulders and the foot. Some spinnaker designs increase the foot round or shoulders – within what class rules allow – to incrementally increase the area of the spinnaker. But beyond a known amount of foot curvature, or additional shoulder area, the fair shape can no longer support the additional area and that portion of the sail will fold/collapse, or flap, in use. The designer can stop this happening by altering the fair shape of the spinnaker, frequently by adding more horizontal curvature in the foot, or even creating a discontinuity where the cloth comes in, then out, and then in again at the actual foot. You can see some of these effects in the following spinnaker images.

Figure 6: You can see the vertical discontinuity at the foot. This is to support a bit more foot round than the fair shape can. Image from Keven Piper.

Figure 7: Both the nearer red spinnaker and the following blue spinnaker are showing an "in, then out, then in" to support more foot round. Image from Christophe Favreau via FB.

Figure 8: See the sharper radius vertical curve near the foot? This spinnaker design has also given up a fair vertical curve near the foot to support a little more foot round. Image from FB.

The shape distortions in the above images support slightly more sail area, but at the cost of keeping a fair curved shape. The crosscut panels also have off thread axis loads, and will stretch more under load, and over time. With all this in mind, our designer chose a VMG-oriented shape with a full triradial panel layout with no horizontal crosscut panels. Consideration was given to how the spinnaker would fly in pole back mode. It may be a little fuller than some other sailmaker's VMG designs.

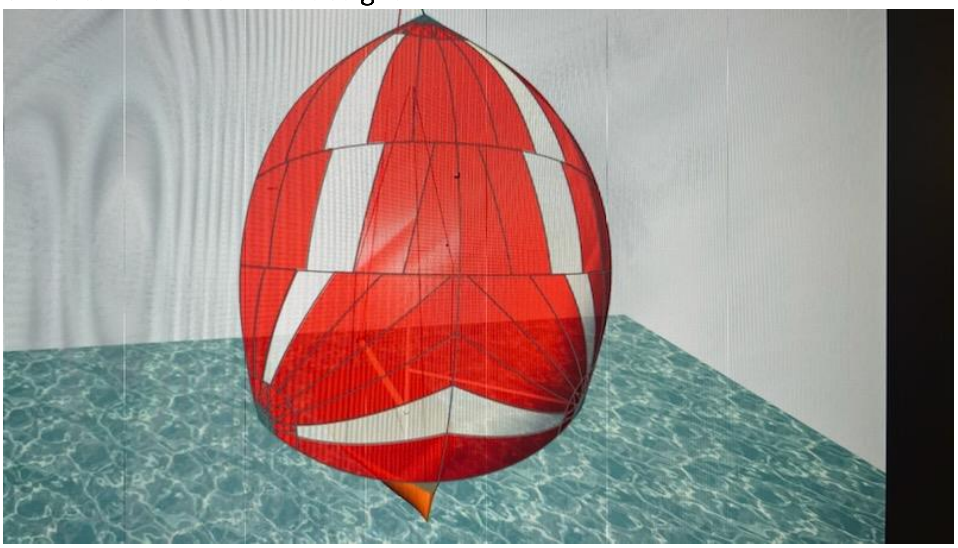

Figure 9: This rendering is from Keven Piper and the Azure Sail Design Software. This is the KSL 505 spinnaker.

With the selected warp-oriented spinnaker cloth and radial panel layout the primary loads placed on the sail line up with the stronger warp threads. The spinnaker will distort less under load, and the leeches won't get as tight. The spinnaker should also last longer as the cloth will stretch less over time. A smooth fair shape with no compromises or distortions would have better flow and be easier to fly, so the design – and the resulting spinnaker – is fair horizontally, vertically, and at any angle that you look at it.

Figure 10: The First Prototype KSL 505 Spinnaker flying in very light air. We decided the retrieval patch (which was in the center of the sail) was too high, and lowered it after this image was taken. Image from Ali Meller.

Figure 11: The KSL 505 Spinnaker on the Water. Image from Sue Fraser.

Figure 12: Note the smooth fair curves and no distortions at the foot. Even in a fresh breeze there is no stretching and changing of shape, as the warp threads line up with the loads on the spinnaker. We are still discussing if the spinnaker pole outboard end should have been slightly higher. Image from Sue Fraser.

You don't see creases coming out of the clews and extending into mid panels. You don't see distortions in the foot. You don't see folds/creases in the head because the sail is full enough to support the shoulders it has and is not trying to support more shoulders than it can. And you don't see significant bias loads – diagonally -- on the ripstop cloth.
The sail is fast, easy to fly, and should keep its fast shape longer in use.

The prototype KSL 505 spinnaker was used by Kyber Lovshin (crew) and Ali Meller at the Eastern Canadian Championship where they won three of the four races. Kyber commented after the event that the spinnaker was very easy to fly. In some of the heavy air gybes, the kite stayed full through the gybe, even while the original spinnaker pole was retracted, the main gybed over, and the new spinnaker pole launched.

The only change we made to the design after this event was to lower the retrieval patch to put it at the same height as some of the other existing spinnakers used in the 505 class, so it would work well with existing length spinnaker halyards.

The KSL spinnaker was also used by Robert Bartlewski at the OHCC coaching/training session at Outer Harbour Centreboard Club at the end of September.

We chose to use two spinnaker cloth colours to emphasize the triradial panel layout. Red and white are KSL's, and Canada's, colours.

We can deliver a two-colour "lightning bolt pattern" spinnaker for the same price as a single colour spinnaker. Red, blue, and white are the most common spinnaker cloth colours, and tend to have the best stretch numbers. The prototype Albacore main and jib are being tested, and we are working on the 505 main and jib.

The images used in this article were grabbed from other articles (thanks to Keven Piper and his Azure software), directly from Keven, from Facebook posts (some of the images may be from long time 505 class photographer Christophe Favreau), and from snapshots taken by Ali Meller and Sue Fraser.