Skinning without a Needle:

Fastening a skin around a kayak or boat frame, using splines — an open-source project?

Text and photos by Robert Morris

Introduction

One of the lovely qualities of the skin-on-frame boat-building experience is the relaxed but steady tempo of the building process. I enjoy the opportunity to talk with my students, and there is plenty of time to look carefully and check that the lines of the boat are attractive and sweet. There is also ample time to dwell on the thought: "There must be an easier, faster or better way of doing this," and to contemplate changes to the design, the tools, or the building process. This article describes my exploration of: "There must be a different way to put the skin on my kayak."

Most of the "better way" ideas I've worked on have been tempered by the knowledge that radical boat-building experiments can trigger the biological process of natural selection. Like warming up a chili gradually, taste testing with each added pinch of pepper, I prefer to creep toward change, making incremental modifications over the course of building several boats.

Some ideas, however, are extremely difficult to develop gradually. They are so different from existing practice that they can only be fully assessed by trying them out. Like skydiving, there is no real way to ease into a commitment. You either do it or you don't.

In 2005/2006 I took a year off from kayak building to study at Simon Fraser University. While that year was among the most exciting and challenging in memory…sometimes during slow moments my thoughts would drift to kayak building. One of the things I began to turn over in my mind was an old problem of skinning without needle and thread. I had been wrestling with this particular puzzle for about 10 years. I've long wanted to experiment with waterproof, non-woven materials, such as Mylar and vinyl, but many of these would tear if sewn. Losing the need to use thread would open up a huge inventory of materials, each with its own unique set of physical attributes.

In school, without the pressure to build, I could indulge in a lot of mental modeling, doodling, and problem solving. Gradually, over a few months, I developed an idea that wedges or "splines" could be used to fasten the skin into a groove or grooves in a gunwale or stringer. I spent the next year thinking through and refining the idea, popping into my shop to machine small sample sections of gunwale, and hunt for appropriate materials. With most obvious bugs worked out, I then successfully skinned four kayaks, with increasing ease and finesse.

The seed of this idea was the memory of making a silk-screen frame where the fabric was fastened by rope wedging it into a groove. Splines are familiar to most of us as the fasteners holding screens to window frames and screen doors. While anyone with an active dog can tell you it's easy to remove the screen from a door or window, it is much more difficult to take apart a printing screen. This is because the varnish on the border and frame of a printing screen glues the spline into the groove and the fabric to the frame. This system can withstand huge forces shearing the joint, and it nicely resolves the difficulty of mechanically fastening an elastic material to a rigid material.

If polyester fabric could be held in a screen frame, I thought, couldn't nylon or any other membrane be held in a boat frame using the same system?

The instructions that follow explain the answer to that question. I have adapted a method to skin kayaks with splines rather than thread and needle. As it stands, I'm confident in the strength and leak resistance of the system, as outlined in the instructions. I think that this is just the beginning of an idea not fully developed, but with enormous potential for experimentation and development. I like the idea of open-source development and would like to see how the idea of skinning with splines can be evolved. I want to share the results of my experiments with the Qajaq USA community and see how far and wide they can be stretched. I have included notes on my development process (see sidebar) because I think that my errors, false starts, and misunderstandings are as important to fellow builders as descriptions of what worked.

Materials:

(1) Skin
(2) Adhesive
(3) Spline material (cotton sash cord)

Tools:

(1) *Either* a ⅛″ kerf x ½″ depth "slot cutter" router bit and router or a ⅛″ kerf table saw blade, and 1″x 4″x 12″ pine or other softwood

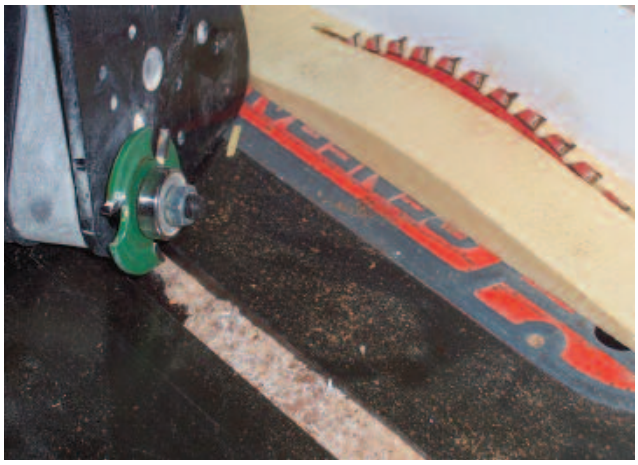
(2) Spline roller — the spline roller has a grooved wheel on one end and a crowned wheel on the other.

(3) Hammer
(4) Hardwood stick ⅛″ thick by 1½″ wide by about 6″ long
(5) Utility knife with sharp blade
(6) Scissors
(7) Thumbtacks (only for raw woven material)
(8) Carpet tape
(9) Large syringe and brush or tube of adhesive with applicator nozzle

Preparation:

(1) Before the gunwales are bent, cut a groove ⅛″ wide, ½″ deep, centered down the full length

of both gunwale tops. This is easy with the wing cutter in a router. If you prefer to use the table saw you need to make a sub-table. Take a piece of wood 1″ x 4″x 2″ and make a piece to sit on top of your table saw throat plate, as illustrated below. This will allow you to cut a saw kerf of constant depth in the shaped top of your gunwales. Ensure that the throat plate is fastened to the table saw securely so it cannot move in relation to the blade as you cut.



The two options for ripping the spline groove are a router bit and a table saw blade through a shaped sub-table. Both cut ⅛″ wide and are set for ½″ depth of cut.

(2) Plane or radius the top outside edges of the gunwales ⅛″. The softened edge will allow the fabric skin to adhere to the edge of the gunwale when varnished or painted. The strength of this fastening system is supplemented by the adhesion of the skin to the surfaces of the gunwale. It also eases the process of drawing the hull skin snug as the spline is driven into the groove (see step 10).

(3) Build your frame *without* a breast hook. If you have decided to use a breast hook, the outside ⅜″ needs to be glued to the gunwales. As seen in the photo below, when the spline groove is cut, the outside edge of the breast hook would be cut off and fall away. If you want a breast hook, you can fit one that sits between the gunwales, like a deck beam, following the techniques used for measuring, cutting, and fitting the flat deck beams.

Notice how the spline groove cuts the outside sections of the breast hook away. The only solutions are to avoid using a breast hook, use adhesive to hold the pieces to the gunwale, or double the thickness of the breast hook.

(4) When you kerf-saw the gunwale tips to fit them together, the measurement across the top edge of the gunwale tips must equal your stem thickness. This can be easily accomplished now or may be dealt with later by using thicker stock to make your stems.

The inside edges of the spline groove meet in a point and the outside dimension of the gunwale tips is the same as the stem material to be used, in this case just shy of ¾″.

(5) When you finish your frame and oil the wood, try not to get oil in the groove. If you are using untreated woven fabric, avoid oiling the top or outside faces of the gunwales.

Notice the smooth transition from two spline grooves to one. The groove wraps around the tip of the stem, but does not go any further.

The Deck:

(6) Lay your skin material over the frame of the deck, and temporarily fasten it so it will not shift around. Leave about 2″ of extra material outside the groove. Ensure that it is not twisted or wrinkled.

Skin is stretched over the deck of the kayak first pulling out gross wrinkles and ensuring some degree of longitudinal tension in the skin.

(7) Trim the skin to the shape of the deck, leaving about 2″ of surplus material on each side. If your kayak is 22″ wide, for example, the skin at the widest point should be 26″ wide.

Measure, mark and cut 2″ of surplus skin.

(8) Use a syringe or brush to wet the inside of the groove with adhesive. In the case of fabric, use the polyurethane, varnish, or paint that you will be using to waterproof the hull. Other materials will require different adhesives.

(9) Cut two pieces of cotton sash cord, each the length of your boat. To prepare the cords, saturate them by soaking in the adhesive. To keep things from getting totally messy, before use, wring them out by pulling them between two pinched fingers. Wet cord will provide a reservoir of adhesive to fully saturate the seam. Dry cord might starve the seam of strength.

(10) Starting at the cockpit on one side, working first toward one end, then toward the other, force the cord into the groove over the deck skin material. Use the spline roller to force the spline down to the bottom of the groove, trapping the skin under it. Try to keep the skin straight and even. It can be easier if you first force the fabric down with the roller, then push the sash cord in after.

An extra pair of hands help to tension and hold the skin as you roll the spline in. It is a good idea to wedge the spline just in the top of the groove along the whole boat before forcing it down to the bottom of the groove. This prevents large wrinkles from being formed as the skin is pulled into the groove.

(11) Repeat the process on the other side of the kayak deck. Watch that the skin is evenly tight. If you notice that it is not tight, pull it out, retighten the fabric, and try again. This can get quite messy, very fast. I *highly* recommend the use of gloves. You need to make every effort possible to keep the wet polyurethane or other adhesive from dripping or soaking the skin more than absolutely necessary.

(12) At the point where the cords meet at the bow and stern, trim them flush. One cord will stop and the other continue to the end of the stem.

(13) *Carefully* use a fresh, sharp, razor knife to trim the skin just below the top of the groove. The loose end will be trapped and sealed inside the groove in the next steps. Trimming should not be rushed. One slip can ruin your work.

When trimming the deck, angle your knife and trim the cloth inside the groove. This leaves a bit to wrap around the first spline as the second spline is forced down on top.

The Hull:

(14) Turn the boat over and position the skin along the keel stringer. Use tacks for fabric skin, or tape for non-woven materials, to temporarily fasten the skin to the gunwales.

(15) Flip the kayak right side up and trim the hull skin the way you did the deck, leaving 2″ of extra material around the edges.

(16) Use a syringe or brush to wet the inside of the groove with adhesive. In the case of fabric, use the polyurethane, varnish, or paint you will be using to waterproof the hull. Other materials will require different adhesives.

The polyurethane is dry and trimming begun. Notice the wrinkle. This could have been pulled tight before the polyurethane dried.

(17) Starting at the cockpit on one side, working first toward one end, then toward the other, and removing the temporary fastenings as you go, force the pre-saturated cord into the groove over the deck skin material so that it is flush with the surface of the gunwale

(18) Use the spline roller to force the spline down to the bottom of the groove, trapping the excess material from the deck skin under it. You want to compress the first layer of saturated cotton cord, squeezing out the polyurethane. This will wet the hull fabric and the second spline inside the groove and eliminate any air spaces.

(19) Repeat the process on the other side of the kayak deck. If you notice that the skin is not tight, Pull it out, *slightly* retighten the fabric, and try again.

(20) On the tops of the stems at the ends of the deck, work with the cord on one side, fastening the skin on that side first, and then do the other side. The smaller the diameter of the kayak, the shorter the length of material available to stretch into shape. This is particularly noticeable toward the ends of the kayak. Picture the difference between stretching one elastic band or stretching five tied end to end. The greater the total length the more extra material available. This means that you must avoid cutting the skin too small at first, because you will not be able to stretch it enough to fit. If you do happen to cut the skin too small you can peel it back and shave down the size of the stem as an alternative to having to start again with a new skin.

(21) Proceed around the front of the stem. I've found that a piece of scrap wood or steel a bit thinner than ⅛" makes a good caulking iron to hammer the last little bit of cord over skin into the groove. Many layers of adhesive will seal the exposed cord, but it should sit slightly below the surface of the stem. If it does not, open the skin up and deepen the groove slightly with a hand saw.

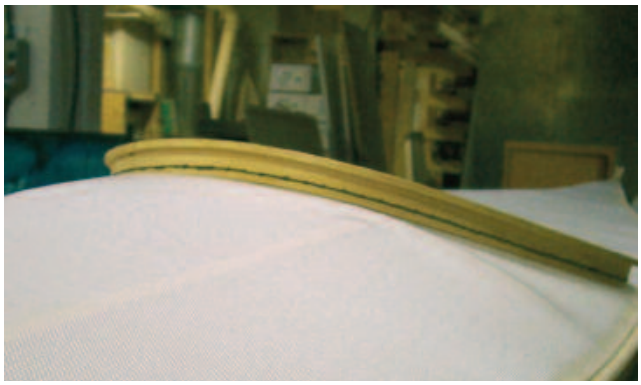
(22) When the adhesive is dry, carefully trim the excess hull material

(23) Saturate the exposed spline and groove with adhesive.

Completed stem.

The Sewn Cockpit Rim:

(24) In the case of woven skins, the cockpit can easily sewn in, because there is no center sewn deck seam to deal with. If you are sewing in your cockpit, drill the sewing holes ¼″ from the bottom of the rim, ½″ apart, and trim the fabric ¾″ from the inside edge. Be sure to sear the edge of the fabric before sewing. You can use piping or a simple fold under the fabric to finish the edge.



Because a deck with no center seam has no slack skin to pull up into the rim, it needs to be sewn closer to the bottom of the rim. This means the stitches need to be spaced closer together.

Splined Cockpit Rim:

(25) For non-woven skins or the sewing-adverse, you need to make a cockpit with a thickness of ½″ (not including the lip). The height of the rim must be 1″ or more. ⅜″ from the bottom of the cockpit, rip a ¼″ deep by ⅛″ wide groove. Rounding off the inside bottom edge will increase the surface area that the skin can adhere to.

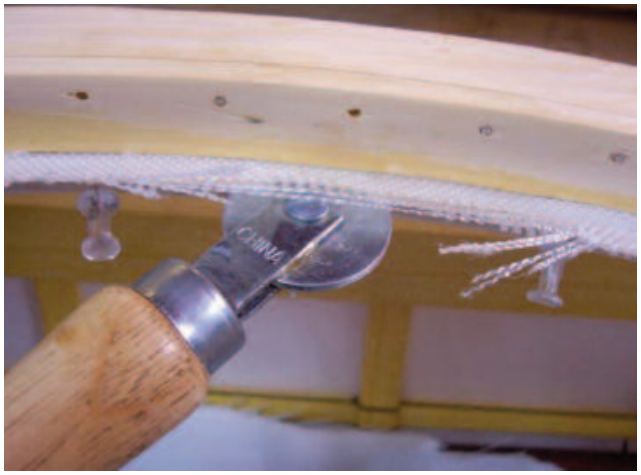
(26) Using pins, tack the skin below the cockpit groove at the port, starboard, fore, and aft points, like the points of a compass around the rim. Don't pull the skin very tight. Pin halfway between the first 4 pins then halfway between all 8 pins. Those 16 pins should be enough to hold the cockpit in place level and straight without getting too much on the way of the splining process.

Note the ends of the ⅛″ dowels, the ⅜″ lip separating the spline groove from the edge of the cockpit rim, and the spacing and locations of the tacks positioning the skin in preparation for trimming the fabric and inserting the spline.

(27) Trim the skin flush to the top of the rim. This ensures that there is enough material for the spline to hold when you bed it in the bottom of the groove. You need to trim this material because the skin cannot be pulled up and into the groove otherwise. Trim closer than 1″ with caution. This is your margin of error, and if you cut it off, it is gone.

Note how the untrimmed cloth cannot be pulled snug to the inside face of the rim, but the trimmed edge can easily be pulled flush to the inside face of the rim.

(28) Without removing the pins, dry-fit the spline and cloth to ensure that you have a good fit and get a bit of practice snugging the cloth. You may need to remove the pins and pull the cloth tight, then replace them, in order to snug the cloth.



Note how much of the fabric is pulled into the spline groove. The fabric was trimmed flush to the top of the rim. You can see how vulnerable the raw edge is to fraying. There is little margin for error. When in doubt, sear the edge!

(29) Pull the cord and spline out of the dry groove. Lay a plastic garbage bag in the bottom of your boat to catch adhesive drips.

(30) Saturate the inside of the groove with adhesive. Soak the spline with polyurethane before insertion.

(31) Wearing rubber gloves, working from the one side of the rim, and starting with the middle of the spline cord, work around the rim, forcing the skin into the groove using the cord. If you tension the skin too much, it will pull out either from the cockpit rim or the gunwales. If you do not introduce enough tension, the skin will be wrinkled and the cockpit will move. This sounds scary, but is really simple to judge once you are doing it.

(32) After the adhesive has dried, trim the skin just below the edge of the spline groove using a very sharp blade.

(33) In the case of nylon or polyester, shrink the fabric once the adhesive is dry.

(34) If needed, waterproof or dope the skin, ensuring that you put as much adhesive as possible into the spline grooves.

(35) Install deck lines and fittings. The deck lines should load the frame, not the skin.

(36) Launch.

Notes:

(1) One potential option would be to glue in a decorative wood spline above the cotton splines. This could either fill the depth of the groove flush to the surface of the boat or could sit slightly proud of the surface. A higher spline could be profiled to cover and seal the edges of the skin where it curves around the edge of the groove. A T- or mushroom-shaped profile glued to the surface on both sides of the spline groove would add yet more strength and protect the seal from abrasion.

(2) Spline grooves cut in stringers and gunwales—or even dedicated "spline rods"—could be used to tighten skin on kayaks skinned with non-shrinking material or material that slackens easily. The process would involve tightening after skinning by driving splines into grooves, pulling the skin tight from the middle rather than the edges. Could a T-profile keel wear strip be fastened this way, tightening and protecting the hull simultaneously? A ¼" x ⅛" spline groove can pull ½", and a ½" deep spline groove could pull 1"!

The Splined Baidarka

This baidarka has had a few modifications to my usual practice to allow for a spline-fastened skin. The main issue that makes skinning the baidarka different from skinning the Greenland kayak is the complexity of the bow and stern forms. The fact there is a stringer running down the center of the deck allows the use of a single piece of skin rather than the two-part skin found on the Greenland kayak.

Note the single spline groove down the center of the deck stringer

Both the bow and stern deck stringers are grooved ⅛″ x ½″. These grooves extend down to the bottom corner of the keel stringer at both the bow and stern, along the center lines of the bow and stern structures.

The spline groove extends right to the bottom of the keel.

The cockpit ends of the stringers feather out to nothing. The groove should be brought flush to the bottom of the stringer (perhaps cut ⅛″ into the deck beam?)

The bow end of the bow deck stringer is rebated into the bow plate to enable it to feather out to flush at the tip of the bow, but still hold the splines and skin. I sewed the skin where the top and bottom meet.

Where the spline and skin run under the cockpit rim, the splines are cut flush with the outside surface of the rim. Keeping the splines from wrapping around under the cockpit rim reduces the bulk of the seam the skin to lay flat against the rim and also wrap around the rim spline. Inside the rim, where there are four layers of fabric formed by the two doubled over halves of the seam, the layers of fabric trapped between the rim and the outer layer of skin need to be trimmed so that they do not extend as far as the groove. Four layers of skin are too bulky to force into the cockpit rim groove. If you tried, you would probably split the rim at the groove

Note that the double layer of cloth inside this Baidarka cockpit rim. The spline was cut off outside the rim because it would have been too bulky to wrap into the cockpit spline groove. This is not an issue with kayaks splined at the gunwales

It is impossible to pull the skin into the groove at the base of the jaw. In fact it is difficult to get closer than an inch to the base of the jaw with the splined skin. I sewed the skin using very small stitches.

Note the skin cannot be forced into the spline groove near the base of the jaw.

Another solution would be to make a 4″x 8″ skin rectangle. This would be splined into the turn of the jaw before the rest of the skinning begins. The main skin would then be sewn to this piece to make up the required material.

Skin the boat as well as you can, getting as close to the jaw as possible, then sew the patch to the skin where necessary. If you want to avoid sewing at all, you could carve a spline groove around

Note position of rectangular skin material. The skin can be sewn to this filler piece.

sides of the turn of the jaw so there is room to insert a filler with splines. Doing so would require bedding the top and bottom halves of the bow jaws with Sikaflex or 3M 5200 to waterproof the joint this would expose to immersion.

Development process — what worked & what didn't

On the Greenland kayaks that have been my initial test beds, the most reasonable places to put the spline grooves have been along the tops of the gunwales. This position would work fine for the hull, as the top and outboard face of the gunwale provide a lot of surface for the fabric to adhere. The deck presented problems, however. I worried that the cockpit and masik could be high enough above the deck that that angle keeps the fabric off the top surface of the gunwale. This means that unlike with a silk-screen frame, in this area, adhesion of the fabric to the frame is restricted to just the inside the groove. The skin tension between the gunwale and cockpit act to pull the fabric up, out of the groove. I worried that without the resistance to shear provided by adhesion to the gunwale top, the cloth and spline would simply be pulled out of the groove. How could I keep the spline in the groove?

For a long time I was stalled, playing around with wedges and other shapes for wooden splines. I thought that the shape of a spline could lock under tension, the way blades are more firmly locked into planer or jointer cutter heads. In the end I realized that for most home boat shops, this was a dead end, not only because it required too much technology, but that the high degree of precision required for success seemed to be contrary to the spirit of the boats. I needed a spline design that could be easily and inexpensively made with minimal technology.

My solution to the fabric pulling up toward the masik was made up of two parts. I would install

the deck skin first, and the hull skin second. I also decided to use square wooden splines cut with my table saw and planed to thickness and width. The square shape would prevent the fabric from moving by providing greater surface area for gluing parallel to the sides of the groove. The pressure of a second spline over the first, the deck spline, along with maximizing the surface area for adhesive, would hold the deck skin tightly in the groove.

The problem I ran into with the square splines used on the first kayak was that the increasing tension of the fabric as the splines were hammered in, tended to make them twist inside the groove. It was difficult to judge the pre-tensioning

I want to share the results of my experiments with the Qajaq USA community and see how far and wide they can be stretched.

of the cloth to tighten the deck, and still prevent the splines from twisting. One of my splines did rotate, and as it turned, it forced its groove open. The result was a three-foot long longitudinal crack in one gunwale, running from the outboard face to the bottom of the groove. I repaired the split inside the skin with a syringe, clamps and epoxy, but I could see that the square wooden splines would be too problematic to recommend them to other kayak builders.

I decided to use cotton cord splines, exactly as I had long ago for my silk screens. In this plastic age, cotton cord turned out to be surprisingly difficult to find. I finally turned up cotton sash cord in the window section of Home Depot, along with a spline roller. This is a tool that looks like a double-ended pizza cutter with 1-inch wheels. It is the perfect tool to evenly force a rope spline

The seed of this idea was the memory of making a silk-screen frame where the fabric was fastened with by rope wedging it into a groove.

down into a groove. While sash cord isn't square, I think that it actually makes a better spline, because it is soft enough to apply even pressure, pushing the skin into tighter contact with irregularities in the texture of the groove. I figured that compressed into the bottom of a groove, it wouldn't be round either, and locked in with cured polyurethane it would not be twisting or rolling.

The cotton spline worked beautifully, and the skin went onto the decks and hulls of the next two kayaks easily. I experimented with wrapping the skin over top of the second spline to get a tighter locking butt joint, but this created a lot of difficulty with controlling skin tension. I pulled the spline and reverted to the pattern described.

The main problem I had with the second boat was accidentally cutting the edge of the deck fabric while trimming the loose ends of the hull fabric. This can be fixed with polyurethane bedding compound such as Sikaflex or 3M 5200 if the problem is near the bow or stern. Amidships, though, you would have to pull the skin off and start again.

I rejected using D-rings to fasten the deck lines because the stress on the skin close to the seam could pull the skin out of the groove. I've used

the traditional method of wedging a leather line passed through a hole in the gunwale, which loads the gunwale rather than the skin. Using pad eyes (inchworms) or screw eyes would also work.

The fourth kayak worked like a charm. Total time spent fastening the cloth to the hull was 2½ hours, including coffee and discussion time! The cockpit rim took another hour because I sewed it on the deck. My next kayak, I will be using the spline method to fasten the rim as well as the hull and deck.

In trying to work as much as possible from the known to the unknown, so far I have only skinned with the 11.5 oz ballistic nylon I have used for almost all my boats. I would like to experiment next with Mylar or polyurethane film. I also think I'll soon be trying silk waterproofed with wax. I was once told that this was the material used on early slalom kayaks, and I would like to see how lightly I *could* build a recovery kayak.

Robert Morris, the author of Building Skin on Frame Boats, *began building SOF kayaks in 1993. The author of several magazine articles, Robert has also appeared in the Canadian National Film Board documentary* Caribou Kayak *about the project he, his wife, Marianne Dupre, and Mark Reuten worked on in Kugaaruk, Nunavut, building Netsilingmeot kayaks with three community elders. Robert has recently closed his business Brewery Creek Small Boat Shop. He wants to spend more time with his family, to concentrate on his new career teaching high school, and to focus his kayak-building time on research and development. Robert hopes this article represents the first fruits of his shift of focus.*

Photo: Tom Milani