

The Truth About Foam Cores in Greenland Style Kayak Paddles.

From time to time I am asked about the foam cores in my paddles. Also, I notice that there are reoccurring conversations in the Greenland Paddling community about the virtues of foam cores in composite paddle construction. I've always tried to answer the questions my customers have in the simplest and most direct manner possible. Usually, the explanation I am trying to offer quickly digresses into an engineering lecture. Moreover, much of what I read in forums and listen to in casual conversions fits into the realm of conjecture and opinion rather than fact or research data.

"I only build my paddles one way: with a core."

For several years now I have been building carbon fiber Greenland style kayak paddles. I did my research before I began building my carbon fiber paddles. I applied that knowledge to my paddle building process once I felt I had a clear understanding of the engineering principals and practices involved. I only build my paddles one way: with a core. The core is the base of my paddle from which all else is supported. The core is a fundamental structural element which is vital to the integrity of the paddle. If the core is unsound then the paddle will also be unsound.

The Basics

Simply put, the core is responsible for keeping the exterior walls of the paddle; the exoskeleton as it were, from converging under stress. Any measurable amount of convergence or collapse of the walls leads to inevitable structural failure.

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For all intents and purposes, my carbon fiber Greenland paddles should be considered a "sandwich" type construction. "Sandwich theory" describes the behavior of a beam, plate, or shell which consists of three layers - two face-sheets and one core [1].

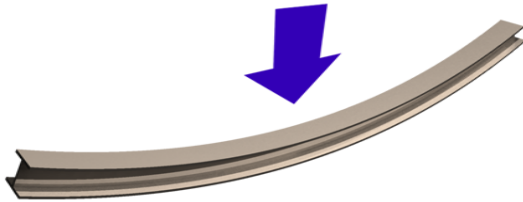


Think of a garden hose without any water pressure. That hose is easily kinked when you try to bend it. That is because there's virtually nothing preventing the walls of the hose from converging and collapsing except for the inherent strength of the hose material itself; the "skin." Now think of the same hose but this time, with water pressure in it. Bending the hose is much more difficult when compared to the hose without water pressure. The water pressure in this example basically represents the basic function of a core; it keeps the walls of the hose from converging under the load of a bending force .

Properties of sandwich structures [2]

The strength of the composite structure is largely dependent on two factors:

1. The outer skins: Think of an I-BEAM. If the sandwich is supported on both sides, and then stressed by means of a force in the middle of the beam, then the bending moment will introduce shear forces in the material. The shear forces results in the bottom skin being in tension and the top skin being in compression. The core material spaces these two skins apart. The thicker the core material, the stronger the composite. This principle works in much the same way as an I-beam does.



2. The interface between the core and the skin: Because the shear stresses in the composite material changes rapidly between the core and the skin, the adhesive layer also sees some degree of shear force. If the adhesive bond between the two layers is too weak, the most probable result will be delamination.

Now we can see that there are three important properties to consider in the construction of a composite foam core paddle.

1. The strength of the skin.
 - a. There is little debate about the strength of carbon fiber. So if carbon fiber is being used in the paddle's construction, you've got the best material for the job and the focus really shifts to the core material.
2. The compressive strength of the core material.
 - a. Simply explained as the difference between squishing a grape vs. a coconut. Whereas in this example the coconut has the high compressive strength and the grape has nothing. The Compressive strength of the core material is vital since it will determine whether or not the core will deform or be displaced under a compressive load.
3. The shear strength of the core material.
 - a. Shear strength is largely a function of the friability of the core material. [5] However, compressive strength is also greatly affected by how friable a core material is. Nonetheless, if core material has friability it is also a liability.

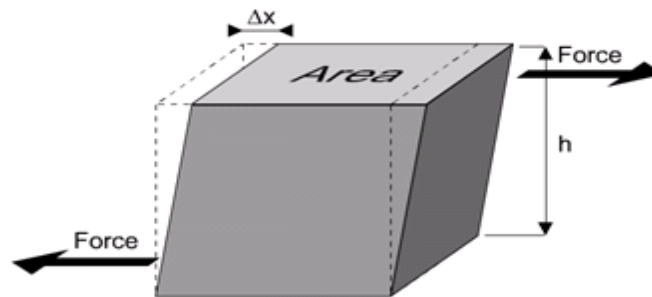


Think of a cracker and a sponge. Think about scratching the cracker with your fingernail and then think of the sponge. Now the cracker will crumble a bit and sponge will not. The cracker is friable and the sponge is not.

More About Shear

Shear is the force a core sees when the skin of the paddle is trying to slide along the surface of the core. It's not hard to imagine this force being present as the paddle tries to flex under a load. Shear strength is the ability of the core to hold onto the skin and not let it go under these stresses. When the paddle is initially being built up on a solid core, the pliable carbon fabric is more or less being glued down to the core with a resin of some sort. Once the lamination is finished and the resin is set, the carbon fiber should be permanently attached to the core. This is where the shear properties of the core material come into play.

If a core material is friable, it will not hold onto the skin of the paddle very well as that skin tries to slide along the surface of the core under a shear load. ***By far the best core material will be non-friable.***



Not All Foams Are Created Equal

In fact, there are many different kinds of foam and most of them are unsuitable as core material for building carbon fiber Greenland paddles. ***There are not many foams a hobbyist can get their hands on to experiment with. Two common types can be readily found at the home stores:***

1. Polystyrene foam
 - a. The common pink or blue insulation board.
 - b. Expanded bead sheets: similar to what a Styrofoam coolers are made of.
2. Polyurethane
 - a. insulation boards.
 - b. 2 part pourable foams
 - c. foam in an aerosol can.

Then there are the foams specifically engineered for composite work. “Structural foam cores are manufactured from a number of thermoset and thermoplastic polymers including” [3]:

1. polyvinyl chloride (PVC)
2. polyurethane (PU),
3. polystyrene (PS)
4. styrene acrylonitrile (SAN)
5. polyetherimide (PEI)
6. polymethacrylimide (PMI).

What separates these foams from each other besides their chemistry is their mechanical properties. The two likely candidates for a foam core material for use in a carbon fiber Greenland paddle is going to be the **PVC** type foams and **SAN** type foams. I use Corecell M-foam M80 (SAN) for my paddles. [4]

Friable materials such as polyurethane or polystyrene foam will not perform well at all under shearing or compressive loads. They will quickly degrade and allow delamination to occur. This is what you can expect using these types of core materials. In contrast; PVC foams and SAN foams are not friable at all. Cores made from these materials do not degrade and will not succumb to compressive and shearing loads; they will not promote delamination and the subsequent structural failure of the paddle

Polystyrene foams and polyurethane foams provide very poor performance as cores material when compared to Corecell or PVC; they do not have the mechanical properties needed to produce a viable sandwich construction in a Greenland paddle. The pink or blue expanded polystyrene foam commonly found at the home stores is NOT in any way a workable solution for a paddle core. These are insulating foams and are of very low density. Their compressive and shear strengths are virtually null.

“Expanding PU foams such as the “foam in an aerosol can ” or any of the pourable 2 part expanding foams are practically useless as core materials.”

Polyurethane foam board is certainly a step in the right direction but what you may find at the home store is still going to come up short regarding compressive and shear strength attributes. Expanding PU foams such as the "foam in a can" or any of the pourable 2 part expanding foams are practically useless as core materials. In fact, their presence inside of a kayak paddle is better described as a **“filling”** rather than a core because that's all they're really doing is filling negative space. The only real value of backfilling a hollow paddle with an expanding foam is to keep the interior space of the shell from filling with water if the paddle were to develop a crack or hole. Otherwise, that foam - is just along for the ride. ***The other important thing to understand about polyurethane foam is that it will absorb water and decompose when exposed to water.***

There are viable alternatives to foam but . . .

My cores first started out being fashioned from long grain balsa wood. I used what was called competition grade balsa wood; 6-7 pound per cubic foot density. Balsa wood has been used as a standard core material in composite laminations for decades. The excellent shear and compressive strength of balsa make it an ideal core material.

It does however, have one drawback: ***it will absorb moisture.*** If the composite skin develops a breach and opens a pathway for water to migrate through to the exposed core, the balsa core will begin to decompose. Nonetheless, my first paddles incorporated balsa wood mainly because I could carve it by hand into the desired shape I wanted. I could use all of the same tools I already had for carving paddles from western red cedar. Additionally, balsa was available in small quantities to match my small budget. Overall, it worked quite well for me and the paddles were excellent.

As business picked up a bit I was able to switch from balsa wood to an engineered foam core material. For me, this was very exciting because the new foam material possessed properties that easily exceed those of balsa wood.

It was much more predictable, lower in overall cost, cleaner to have in the shop, lighter in density thus reducing the weight of the finished paddles and it had much better compressive and shear properties. Eventually, I designed and built a CNC router which I began to use to carve my cores. I designed the paddles using solid modeling software and transferred that 3D shape over to the CNC to be reproduced in my desired core material.

The Shell Game

A lot of carbon fiber paddles are of a shell construction. This results in a hollow interior. In order for this paddle to overcome the compressive forces which can cause the convergence of its walls, the paddle must rely *only* on the inherent strength of the shell. Often, it is necessary to compensate for any weaknesses by adding more carbon or glass to the shell. And that's it, that's all you can do: keep adding material until you get a paddle that won't bend under normal conditions. There is the option of putting structural components such as ribs or pillars inside the paddle but the weight gain represented by those elements will diminish the benefits.

“The other thing you get from adding additional layers of carbon fiber to a shell is an overly stiff paddle that has none the desirable flexibility inherent to a traditional wood Greenland paddle.”

The greatest shortcoming to building a hollow paddle is that if water can get inside it – water will get inside it. Backfilling with expanding liquid foam is about the only thing that can be done to prevent this. You don't get a core that way; you get a foam filled paddle.

Conclusion

You know, I could go on but I think I have illustrated pretty well that there is a profound difference between a real foam core and a foam filling. Additionally, I hope I have given you enough detail for you to see that not all foams are created equal. A core for a carbon fiber Greenland paddle is very specialized and cannot simply be an afterthought. I have not compromised one thing when it comes to the materials used in a NOVORCA paddle. All of the materials I used are engineered specifically for composite work. Each paddle is built one at a time practically entirely by my hands. I used my robotic router to give me a symmetrical and consistent shape for the foam core, but from there on it's all me and my hard work. When you buy one of my paddles, you're getting a work of art; you're getting a well thought out and executed piece of engineering. I care about the quality of my paddles. Call me anytime with your questions.

“A core for a carbon fiber Greenland paddle is a very specialized thing and cannot simply be an afterthought.”

Links:

1. Sandwich Theory: http://en.wikipedia.org/wiki/Sandwich_theory
2. Structured Composites: http://en.wikipedia.org/wiki/Sandwich_structured_composite
3. Core Materials: <http://www.compositesworld.com/articles/getting-to-the-core-of-composite-laminates>
4. Corecell: http://gurit.fangle.co.uk/files/documents/Corecell_M_Foam_v5.pdf
5. Friability explained: <http://en.wikipedia.org/wiki/Friability>