PEAK OF FLIGHT NEWSLETTER

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PEAK OF FLIGHT

How to Make An Ultra-Lightweight Carbon-Fiber Glider Boom

By Tim Van Milligan

In this article, I will describe two ways to make a tapered carbon fiber tube, which can be used for lightweight competition style gliders. The advantage of these glider booms is they are very lightweight and stiff. The disadvantage is that they are hard to make, and can be brittle because they are very thin walled. You may want to use a something else, like a stiff graphite rod that might be a few grams more in weight, but is more durable. But I'll document the process here just in case you want to give it a try. You might have some suggestions for making them lighter or stronger. I'd be interested in hearing your thoughts, and I'm always interested in improving my building skills.

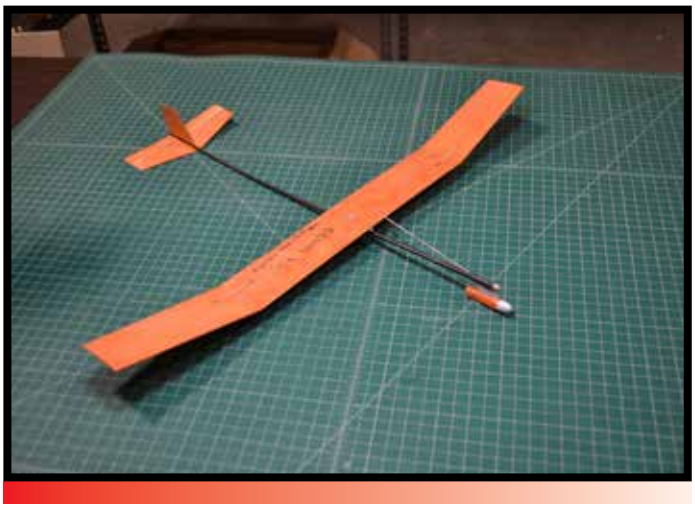

Figure 1: A competition style "scissors-flop wing glider." It uses a carbon-fiber boom in order to keep the weight low.

This past summer, I needed a long stiff tapered rod to use as a glider boom. The glider was a scissor-flop design whose plans I got off the NAR's competition website (http://www.nar.org/contest-flying/fai-spacemodeling/fai-events-for-wsmc/s4-boost-glider/). The fuselage, called the "boom", was a hollow tapered rod that was about 21 inches long. I knew from past experience that the ones made by European countries were in the range of 3 to 5 grams in weight. So that was my goal in this project.

I've got experience making large diameter fiberglass tubes, and it centers around laying the cloth over a mandrel. The key item you'll need to make a hollow glider boom is a tapered mandrel. What I wanted was one made of steel. I like steel because it is easiest to get the tube to slide off after the epoxy has cured. You can use a wax mold release, and when you're done, you can just plunge it in hot water to melt the wax and slide the tube off the mandrel. And steel holds the heat well, so you have a lot of working time to slide it off. And if the epoxy should stick to the steel, you can easily chip or scrape it off without doing much damage to the surface of the steel.

Steel is what I wanted, but I couldn't find a tapered mandrel long enough. I could have used drill rod, but that is not tapered, and for gliders that aren't really desired to have a straight boom. The rear part of the model is heavier and larger in diameter, so it isn't optimized to minimize weight.

The other disadvantage of a thin tapered steel rod is that if you accidentally drop it, you're going to bend it. At that point, it isn't useful for a glider, because any tube you pull off of it will have a curve in it.

But I couldn't find any metal tapered rod long enough for my glider. So I started looking around for something else to use as a mandrel. What I ended up with was a fiberglass fishing rod.

I went down to Walmart and found a number of really cheap fishing rods that could be useful. I just searched through their inventory until I found one that had the right length and that was also cheap. It cost me about $8 or $9.

The first thing I did was remove the mechanical components, like the handle, the string, and the winder, and tossed them in the trash. Next, I had to figure out how to remove the little rings mounted to the shaft that guides the fishing line. I found that they are bonded to the shaft with epoxy.

Removing them was tedious because I had to work slowly to avoid harming the fiberglass underneath. I chipped and carved it way slowly using a sharp hobby knife.

The fiberglass shafts are also painted. I don't mind them being painted, because they were nice and smooth. But since the areas where the rings were bonded on where no longer painted, I really had no choice but to remove the paint too. I just sanded it off in order to get down to the bare fiberglass shaft.

Here is the one absolute must you have to watch out for. The shaft must have a perfectly straight taper. I found this out the hard way, by ruining every tube I tried to make on the mandrel.

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Figure 2: The fishing rod with the paint removed, next to a metal ruler.

After you remove the paint, you have to take a straight long ruler and lay it on the side of the shaft and check for gaps between the ruler and the shaft.

Figure 3: With the straight edge against the shaft, check for gaps. The gaps indicate the shaft is not tapered straight.

If you can see any light between the two, anywhere along the length, you'll never get the final tubes to slide off the mandrel.

I'll tell you a hard lesson that I learned. The cheap fiberglass fishing rods you buy at Walmart are not perfectly tapered. They don't need to be for a fishing rod. But they do need to be for a mandrel where you want to slide off the tube you put over it. The one I purchased had a slight bump near the fat end of the shaft. I didn't notice it until I tried to pull off a tube, and it wouldn't budge. I ended up having to cut it off with a whittling action.

So I spent several hours sanding it so it was finally had a straight taper where the finished tubes would come off easily enough.

Figure 4: The model release wax is applied to the shaft with a paper towel and then buffed off.

Once it was straight, I also sanded it as smooth as possible. The goal is a high gloss finish. On top of that, I put several coats of Part-All High-Temperature Release paste. I've had good success with this type of paste release because it has Teflon in it.

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For the first tubes I made, I used a woven carbon-fiber tube (https://www.sollercomposites.com/CarbonSleeves.html). It is like a hollow rope. To put it on the shaft, you kinda bunch up the rope, which enlarges the diameter and the hole inside of it, and you slide it over the shaft.

Figure 5: Woven tubular graphite sleeve.

Once it is on the shaft, you take a plastic zip-tie and cinch down the tube against the shaft. Then you pull hard on the free end of the rope on the other side of the shaft. That cinches down the tube, like one of those toy Chinese finger handcuffs. When it is tight as you can get it, you cinch it down with another zip-tie on the free end.

Figure 6: Cinch down the ends of the sleeve with a zip-tie.

You cut off the excess tails of the zip ties, and the tube is ready to be soaked in epoxy.

I use rubber gloves for this step. I just mixed up the epoxy and worked it into the tube on the shaft. I used West Systems epoxy for this because I knew from experience that it works well with the Part-All mold release.

The company I got the carbon-fiber tube from also sells a special heat shrink tubing that you can slide over the outside of the tube. It has a special coating on the inside that prevents it from bonding to the epoxy so that it can be removed later. You can take a heat gun and shrink the tube down and it is supposed to push out the excess epoxy. I'm not so sure it pushes out the excess epoxy all that well. But it does leave a nicer surface.

Note that this technique of using a carbon-fiber tube is the same process that a lot of high-power rocketry fliers use to stiff up cardboard tube.

But I ended up not using the heat shrink tubing, even though I purchased it. For one thing, The tube I was making was so small in diameter, that I couldn't get the heat-shrink tube over the top of the zip-tie nub that secured each end.

I also wanted to remove all the excess epoxy from the tube, because the weight was the most important criteria of the tube. The surface finish was a secondary concern. To get the excess epoxy out, I used a bunch of paper towels and blotted it out.

Figure 7: Blot up the excess epoxy with a paper towel.

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When the epoxy is hard, the fiberglass shaft has to be removed from the tube. This is the hardest step of the whole process. It was during this step that I found out how important it was that the shaft has a straight taper with no bulges in the middle. I ended up cutting several of them off, and even gouging the fiberglass shaft in the process. That meant I had to go back to the store and buy another fiberglass fishing pole.

To slide them off, you can't really put the carbon-fiber tube all the way along the shaft. You have to leave a bit of the shaft exposed so you can grip the end and do a tug-of-war in order to pull the tube off. Once it starts moving, it is easy to pull off. But getting it to start moving is a bear. If anyone has a better trick for getting it started, I'd love to hear it.

Once the tubes were off, I decided to sand them smoother. The woven tubes of carbon-fiber are pretty thick because of all the individual fibers that make up the tube. So I wasn't worried too much that the strength would be compromised too much. And I needed to take off some of the weight.

Carbon-fiber tubes sand really easy. Much easier than trying to sand fiberglass. And just like working with fiberglass, you need to wear a dust mask and vinyl gloves to protect yourself.

Figure 8: Cured tubes. The top one is the tube in its raw state, just off the mandrel. The bottom one has been sanded smooth.

The overall tube made using this method turned out about 5 grams. It was fairly stiff, but a little bit flexible. The weak part is where the bundles of fibers criss-cross in the weave. And since I had sanded away the top surface of fibers, I did know in the back of my mind that I did reduce its strength. But it was still "strong enough" for the lightweight gliders I was making.

The one drawback of West Systems epoxy is that it gets soft when the part gets hot. With that in the back of your mind, picture this situation: a matte-black tube sitting in the bright sunlight. What do you expect to happen to the temperature of the tube? Right. It got hot, and the epoxy got soft and the tube started to bend.

The whole purpose of using carbon-fiber is to make a stiff tube that doesn't bend so that the glider parts are all aligned straight. Now I had a tube that was curved because of the epoxy in the matrix.

The only solution to this was to use a different epoxy that could take the higher heat when the rocket glider was sitting in the sunlight. I did find different epoxy from Soller (https://www.sollercomposites.com/Epoxy.html), and I like it a lot. But the problem is that it sticks too good. Even the Part-All mold release isn't enough to keep that from sticking to the fiberglass shaft. Did you guess what happened next? I had to make another trip to the sporting goods section of Walmart to get another fishing rod because I ruined another shaft trying to get a tube off that was bonded using the higher temperature Soller epoxy.

What I needed was either a different mold release or something to keep the epoxy from getting to the shaft.

I ordered and tried some Teflon heat-shrink tubing over the fiberglass shaft. Nothing sticks to Teflon, right?

That was a disaster. Heat shrunk Teflon tubing is high-temperature stuff, and just trying to shrink it down over the fiberglass fishing rod shaft was difficult. I had to apply so much heat to get it to shrink down, that guess what I did to the epoxy in the fiberglass shaft? Yep, you guessed it. I torched it to a crisp.

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Do you see why I wanted a steel mandrel when I started this process? It would have made things much easier.

This article is not a comedy. I swear it. But it was back to Walmart for yet another fishing rod. And I had to start over again. By this time, I'm a pro at removing the rings on the rod and sanding it smooth. I can do it in about an hour now.

The other thing that I know epoxy doesn't stick to is polyester plastic. I'm sure you've noticed this too when you cover your work area with a plastic sheet. Any epoxy spills cure on the plastic and just pop right off when you lift the plastic up off the table.

If only I had a tube of polyester plastic. I could put that over the fiberglass shaft before I put on the high-temp epoxy. That should prevent it from sticking to the shaft.

The other thing about polyester plastic is that you can heat it up and it shrinks a little bit. I was thinking that I could make a sleeve from a plastic bag and gently heat it so it shrinks down tight against the shaft.

I made a plastic sleeve by folding a large plastic bag in half and sealing the top against the sheet down in a line - like a heat-sealed bag that you get a rocket kit in. Then the excess plastic is cut off, leaving a tube.

Figure 9: To make a sleeve, I used an ultra-thin plastic sheet, and sealed it to itself with a MonoKote iron. The plastic was so thin that I had to use a ruler to prevent it from melting too much.

This sleeve was put over the fiberglass shaft and was shrunk down with a heat gun. The result was promising. Except for the seam that is where the edges came together. That was pretty bumpy and had some pin holes where epoxy could get through to the shaft underneath.

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Figure 10: The excess plastic was trimmed off with a hobby knife.

Figure 11: The shaft inside the sleeve. Notice the excess plastic hanging off the edge.

Figure 12: The excess along the edge was sealed down by rolling the shaft under the MonoKote iron. Roll in one direction only!

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What I needed was thinner plastic. That way the seam would be smaller along the shaft. And maybe I could put down two layers of plastic to provide a double barrier to prevent the epoxy from getting to the fiberglass shaft inside the tube.

Do you know where you can get the cheapest, thinnest plastic sheet from? The Dollar Tree store. They sell the wimpiest garbage bags in the world (https://www.dollartree.com/scented-tall-kitchen-trash-bags-13gal-28ct-rolls/858535). But they are great for this purpose (and for making competition-style parachutes too - https://www.apogeerockets.com/education/downloads/Newsletter394.pdf).

The plastic is so thin, that I couldn't make a sleeve easily by sealing the plastic to itself. I found that I should rap it over the shaft first, and then seal it down against itself with a MonoKote iron. Then the excess could be cut off, and the shaft was already inside the plastic sleeve.

But heating it up with a heat-gun was too much heat. The plastic is too thin, and you'll burn holes in it with a heat gun. So I used the MonoKote iron to press the plastic against the shaft (**Figure 12, Page 6**). This worked great because you can control the heat. And the shaft became a little heat-sink, preventing the thin plastic from melting too much. It was just enough to make a glove-tight fit against the tube. And it was so thin, that the overlap was barely noticeable.

I did end up putting two layers of the thin garbage bag plastic on the shaft, to keep the epoxy from getting to the fiberglass shaft underneath should there be any pinholes in the plastic. This worked very well.

Now that I was using this method, getting the tubes off the mandrel was easier too. The plastic would simply tear, and it slid easier off the fiberglass shaft. Not that I said "easier," not "easy." It still takes some effort to get it to start moving off the shaft. But it was better than before.

Unfortunately, it also leaves the thin plastic sheath inside the carbon fiber tube. The weight is minimal, so you can leave it inside if you want. But I found that I could push it out if I ran a long, stiff music wire through the tube from the small end. What happens is that it bunches up the plastic, and then you are able to push the whole thing out of the tube. It looks like the molted skin of a long skinny snake when you get it out. I weighed the amount of plastic that comes out, and it wouldn't even register on my gram scale, it was so light.

Using this technique, I was now able to make some nice tubes. They were good enough for competition.

But I wondered if I could make them even lighter weight and stronger using carbon tow instead of a woven tube.

The advantage of that would be that all the individual strands in the bundle would be running parallel to the length of the tube. This is stiffer than a woven tube because there is no crossover of strands. And I was thinking that it would take less material to get the same strength.

Ultra-light Carbon Fiber Tubes

For this tube, I took the carbon fiber tow and flattened it out to about 3/4-inch wide using the method I described previously in Peak-of-Flight Newsletter 478 (https://www.apogeerockets.com/education/downloads/Newsletter478.pdf). This long ribbon was then laid along the fiberglass shaft, and wrapped around.

Figure 13: Carbon Fiber Tow that has been flattened and spread out.

I used a similar technique that I used when applying the carbon fiber to the balsa wood helicopter blades. I first put some liquid epoxy on the shaft.

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Then I gently positioned the flattened carbon-fiber ribbon on the shaft. Then some rubbing alcohol was drizzled on the shaft. The surface tension of the liquid helped to suck the fibers tight against the shaft so that they stayed down while the epoxy was worked into the fibers.

Figure 14: Laying the flatten tow on the shaft.

Figure 15: A little bit of rubbing alcohol causes the fibers to easily wrap around the shaft and stick down nicely.

As before, the excess epoxy was blotted out, so the minimum amount was left behind in the tube.

Figure 16: Epoxy is applied into the fibers, and then smoothed out with your fingers. The second layer of the tow was applied to fill in any gaps in the tube.

In order to make the surface smooth, I thought about using that heat shrink tubing that I had. But I knew that I wasn't going to be able to slide it over the loose fibers without messing them up. So I thought I'd try the technique of rolling the tube in the cheap Dollar-Tree-store plastic garbage bags, and shrinking that against the fibers.

It is a little messy, but it actually works good because of the surface tension causes the plastic to stick to the fibers. You can lay the mandrel on the sheet of plastic and then roll it up quite well. I put rolled until the plastic was two layers thick. Then I cut away the rest of the sheet and rolled it with the hot MonoKote iron.

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This shrunk and sealed the edges of the plastic. You start in the middle and work toward the ends. If there is excess epoxy, it kinda oozes out, and you wipe it off and continue to roll and shrink it down.

Figure 17: The thin plastic sticks nicely to the wet epoxy. This allows you to see any wrinkles in the plastic. The shaft is rolled up until there are two wraps of plastic around it. Then the excess sheet is trimmed away.

Figure 18: The MonoKote iron is again used to seal the edge and to shrink the plastic tight against the carbon-fiber.

Figure 19: The cocooned shaft inside the thin plastic sheet.

When the epoxy is cured the outer coat of plastic is ripped away. As I said, the epoxy doesn't stick to plastic at all.

Figure 20: The plastic is ripped away after the epoxy has cured.

The surface, while not perfectly smooth, isn't too bad. A little light sanding would be all it would take to make them visually presentable.

I found getting them off the tube was as hard as before. And since the tubes were thinner than the woven carbon-fiber tubes, they were much more

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delicate. I broke several tubes trying to pull them off the mandrel. And when the break, they leave long shards that can easily puncture the skin. Yep, I seriously stabbed myself until I learned to wear thick leather work-gloves when pulling them off the mandrel.

The problem with all the fibers running in one direction is that they have almost no strength longitudinally. In other words, if you start a slit along the tube, that slit will easily snap open the entire tube. You do need something to prevent this from happening.

I ended up putting a layer of tissue paper down over the mandrel first, before applying the carbon fiber ribbon. The fibers in the paper are random enough that it provides some strength that prevents the tube from splitting longways.

Figure 21: Tissue paper wrapped over the mandrel. To get the tissue to stick tight, just add water. Wet tissue rolls easily, even around small diameter mandrels like this one.

The tissue paper was cut into a long parallelogram shape and rolled around the mandrel. To make it stick, I applied a little bit of water. The water loosens up the fibers in the tissue paper and makes it soft enough where you can press it down tight against the mandrel. You have to carefully press it down so that there are no crinkles in the paper, as that would affect how the carbon fiber lays down. You also have to let the wet tissue paper dry for a couple of hours so that it is perfectly dry. Epoxy and water don't mix…

Once the tissue paper is down, the procedure of laying down the carbon fiber tow as described previously is completed. When the tube is removed from the mandrel, it is exceptionally lightweight - only around 2.5 grams. About half the weight of the tube made from the woven tube. And even better, because it is much stiffer. You'd break it before you'd get it to bend even a little bit.

Figure 22: Allow the water to completely dry before adding the epoxy and the carbon fiber tow.

Conclusion

This technique of making ultralight carbon-fiber tubes is probably not for normal rocketeers. I wanted to document this process of making them because someone out there may want to experiment with gliders like I was making. These tubes are exceptionally lightweight and very stiff. They were nearly perfect for what I wanted for the gliders we flew in competition.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: *Model Rocket Design and Construction*, *69 Simple Science Fair Projects with Model Rockets: Aeronautics* and publisher of the *Peak-of-Flight* newsletter, a FREE ezine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.

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