PEAK OF FLIGHT NEWSLETTER

ISSUE 434 | January 10th 2017

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Making Fiberglass Body Tubes: Part 4

By Tim Van Milligan

In part three of this series (found at: http://www.ApogeeRockets.com/education/downloads/newsletter432.pdf), I had really worked out many of the major issues that stood in the way from getting a perfect lightweight fiberglass tube. My goal was to create a lightweight tube that didn't require any post processing to getting a glass-smooth surface. The tubes are just too delicate to be sanding and trying to polish them.

As you read in the last article, I found that using a harder rubber really helped in creating a perfectly uniform surface, without little epoxy pimples on in. And more importantly, I figured out the key ingredient to easily removing the paper thin fiberglass shell from the mandrel. That secret ingredient was to use "Part All Hi-Temp Wax" mold release from Rexco. The stuff contains teflon in the wax, preventing the epoxy from sticking to the aluminum mandrel.

Air Tight

In order to get the weight down as much as possible, I began making tubes with just a single layer of lightweight fiberglass cloth. The slight issue I was having was that the tubes were not air tight. The epoxy was not filling in the gaps in the weave of the fiberglass cloth. As a result, there were little pin holes in the final tube, most notably in the wider straight portion of the tube.

What this meant was that the ejection charge from the rocket engine wasn't pushing the nose cone off the tube. The gases were going out the sides of the tube through the little pin holes. The part that had the most pin holes was on the wider portion of the tube, just above the transition.

I figured there were a couple of causes. The first was that the fiberglass cloth didn't have a nice and straight weave to it. The cloth, if you've ever handled it you'd recognize this, snags really easily. If the strands of glass fibers shift out of position (bunch up), then it is going to leave larger than normal holes in the place the strands should have been **(Figure 1)**.

Figure 1: Close-up showing the gaps in the weave of the cloth. Where the fiberglass bunches up, there is a greater possibility of an air leak.

The solution to this was the spray paint that I used to colorize the cloth. Remember, I was spraying the cloth with paint as soon as I cut out the patterns.

To prevent the cloth from snagging, I changed the order in which I was doing things. Instead of waiting until after I cut out the patterns, I decided to paint it prior to cutting them. Once it was painted, it was much more difficult to move the strands around in the weave **(Figure 2, Page 3)**.

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Figure 2: I painted the fiberglass cloth prior to cutting out the patterns.

In fact, the added benefit was that I found it was much easier to cut out the pattern for the tube if it was painted first. The weave wouldn't shift around, and the patterns stayed in their true shape. For example, if I cut out a rectangle for the straight parts, they didn't shift and become parallelograms. So painting the cloth first actually solved two problems: keeping the patterns true to their shapes, and keeping the individual fibers from snagging and bunching up thereby creating big holes in the cloth.

However, there was one other problem. I was getting the fiberglass cloth from a hobby store in a small little plastic bag. The cloth was pre-folded, which meant that someone else pre-snagged the cloth for me.

In order to minimize the amount of handling of the cloth, you have to purchase it on a roll, not folded in a pouch. Therefore, you can't get it from your local hobby store. You have to go on the internet and order it on a roll.

Figure 3: The color gradient on the rocket to the left was made of pre-painted cloth. The bright colors make the parts easier to find in tall grass.

The other thing that was causing pin holes was the plunging of the mandrel into the rubber mold. As you put it in, the excess resin is squeezed off as it enters the rubber tube. This is a good thing. But the part of the tube just above the transition is squeegeed off for a longer period of time than the end of the tube. So there is less epoxy in this location on the tube.

I found that if I let the epoxy set up for a period of time prior to plunging

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the mandrel into the rubber mold, not as much of it was squeegeed off, which reduced the pin holes.

The good thing was that I could get a tube that was just a bit over 3 grams in weight. So I thought that I had solved all the issues.

Flight testing Reveals a Problem

So I took my perfect looking tube, and built it into a rocket to do some test flights. Everything went well, right until the ejection charge went off. Basically, the heat from the ejection charge took my ultra-lightweight fiberglass/epoxy tube and deformed it into a potato chip. It was utterly useless after one flight **(Figure 4)**.

Figure 4: A warped body tube because the epoxy softened and deformed it.

The shell was too thin, and just couldn't take the heat from the ejection charge.

The solution was an easy fix. I just went back to the old method of putting one layer of tissue paper on the mandrel with the layer of fiberglass cloth. The single layer of tissue paper did add a little bit of thickness and some heat resistance to the wall of the tube.

But I knew I didn't need tissue paper over the entire tube, just near the motor (the transition area) where it needed some heat resistance. I also extended the tissue paper up the straight portion of the tube for about two and a half inches. This was the area that would get the pin holes in it. I figured that the tissue paper would seal up those holes, which it did very well **(Figure 5)**.

Figure 5: You can tell where the tissue paper stops by the slight color change of the tube.

Because of that, I could go back and jam the mandrel with the fiberglass and tissue paper on it into the rubber mold as soon as the second layer of epoxy was put on and still very runny. That would minimize the thickness of the shell and keep the weight of the tube as low as possible.

The extra weight of the tissue paper with the fiberglass cloth boosted the mass of the tube from just over 3 grams to about 5 grams.

I used white tissue paper, because when it absorbed epoxy, it would become semi-transparent. This would allow the fluorescent color of the spray paint to still show through brightly. When I used other colors, it dulled

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the look of the tube. So from this point on, I only buy white tissue paper from the craft store.

The Final Process

Here is the final step-by-step process for making the tubes:

1. Unroll the fiberglass from the roll onto a large piece of cardboard. The cardboard I used was a bit larger than three feet long and two feet wide. Carefully cut the fiberglass so as not to fray or snag any edges. Smooth out the fiberglass so that there aren't any waves or ripples on the surface.
2. Take the fiberglass outside and spray it with fluorescent paint. Allow the paint to dry. It will stick the fiberglass to the cardboard, but it is easy to peel off when it is completely dry.
3. Cut the fiberglass cloth patterns. I could get parts for three or four complete tubes from the 2-foot by 3-foot piece of cloth.
4. At the same time you're cutting out the fiberglass cloth patterns, you can cut out the tissue paper patterns.
5. Clean off your aluminum mandrel using ultra-fine 0000 steel wool. Then wipe it down with a damp cloth. You'll notice that the steel wool leaves some residue on the mandrel, as the cloth will be quite dirty.
6. Immediately after cleaning it, apply a thin coat of the "Part All Hi-Temp Wax" to the aluminum mandrel using a paper towel. This will also seal the surface and prevent oxidation of the aluminum.
7. Before the wax becomes stiff and dry, buff off the excess with a clean paper towel until you get a clean and shiny mandrel. You'll notice that the wax covers the surface easily when it is still moist. But if you wait too long to buff it off, the wax becomes difficult to remove. It comes off in dry clumps instead of being spread smoothly on the surface. In that case, I would suggest buffing it all off, and reapplying it just to make sure the entire surface of the mandrel is covered with the wax. You obviously don't want any spots on the mandrel with no wax, because the epoxy is going to stick to it really well. Because you'll be taking all of the excess wax off, you won't see or feel any areas that you missed. Just take your time to make sure you do this step right, or re-do it if you're unsure.
8. On a piece of flat plate glass, lay down the tissue paper patterns. They will be applied first to the mandrel.
9. Mix up your epoxy. I do small batches of about 10 grams of epoxy.
10. Wet out the tissue paper with epoxy. Squeegee off the excess with a stiff piece of plastic (I use 0.010 thick styrene sheet).
11. Pick up the tissue paper patterns and lay them on the aluminum mandrel. You have plenty of working time, so line up the edges so there are no gaps between the edges where the patterns come together.
12. Repeat the process with the fiberglass cloth. Wet out the cloth on the plate-glass first. Squeegee off the excess epoxy, and then transfer the patterns one at a

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time to the mandrel. But this time, start with the transition piece first.

13. The other fiberglass patterns have to overlap on the edges. I like to keep it to a minimum, under ⅛" (3mm). I prefer tighter overlap, around 1/16" (1.5mm). So both the patterns for the straight portions will overlap onto the transition. Remember, the tissue paper does not overlap, but the fiberglass does **(Figure 6)**.

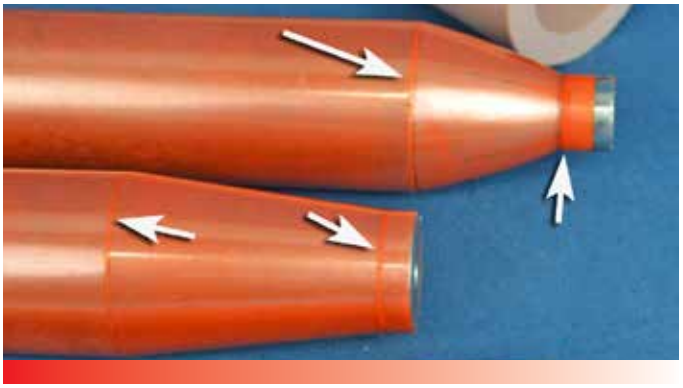

Figure 6: The lighter colored lines are where the fiberglass overlaps each other. You want to minimize the overlap to save weight.

14. Blot up any excess epoxy with paper towels. There shouldn't be much if any, because you squeegeed it all off before you laid it onto the mandrel.
15. Allow the epoxy to start curing for about an hour. This allows it to stiffen up so that it won't shift around as you plunge it into the rubber mold. While it is beginning to cure, clean off the glass sheet with acetone to remove all the excess epoxy.
16. After an hour, apply a second coat of epoxy onto the mandrel. Keep it thin, especially on the motor tube and the transition part of the rocket. While the epoxy is still liquid, slide the mandrel into the silicone rubber sleeve.
17. Put the sleeve and mandrel into the pressure pot overnight at 20 psi.
18. When cured, pull the silicone rubber sleeve off the mandrel.
19. Remove the fiberglass tube from the mandrel. Start by breaking the surface tension of the tube, and working the air bubble with your thumb along the entire surface of the tube. Then slowly pull the tube off the mandrel allowing time for air to work its way in. See the video at: https://www.youtube.com/watch?v=nC-CRh226Avg
20. Trim the ends of the fiberglass tube.

This is the process that I currently use to make thin-wall fiberglass tubes. They come out exceptionally nice, with bright colors and a smooth surface.

The Rubber Wears Out

It took me a long time to get this process down because I had to work out all the steps, the timing on the curing of the epoxy, and the different types of mold releases. During that time, I probably tried to make at least 50 tubes. After I finally got the procedure mostly worked out, I ran into another problem. I discovered that the silicone rubber was losing its slipperiness. The inside of the silicone mold started out shiny like the surface of the mandrel, but over time, it started to look dull.

Essentially, the smooth surface was wearing down during the process of pulling the mandrel out of the mold after the epoxy had cured. There is a lot of friction created when trying to remove it from the silicone mold.

At one point, during the process of pulling the mandrel out, I actually pulled the mandrel completely out of the fiberglass shell. That is when I discovered that the "Part All Hi-Temp Wax" mold release might be working too well. It pulled off too easily -- because it left the fiberglass shell inside the silicone rubber mold. That presented a major problem, because how do you get the shell out of the mold?

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The actual fiberglass tube was ruined of course, because when you pull the mandrel out of the shell there is a vacuum created inside the tube that tries to suck the shell inward. You have to pull the mandrel out slowly in order to let air seep inside during the process. But when I was trying to pull the mandrel out from the silicone rubber mold and the accidentally pulled the mandrel quickly out of the fiberglass shell instead, it created a vacuum that crushed the tube.

Getting the remnants of the fiberglass tube out of the rubber mold was a major chore. I ended up putting more epoxy onto the mandrel, and shoving it back into the mold. I was hoping that the epoxy would grab the shards of fiberglass and allow me to pull it out in one piece. It worked partially, but there were still a lot of tiny bits of the crushed tube in the silicone rubber mold. Those bits left in the mold ended up on the next fiberglass tube I made too.

The lesson learned is that there is a definite life-span to the silicone rubber mold. I'm guessing it is in the neighborhood of 50 parts.

I discovered that I could extend that lifespan somewhat by trimming off the top inch inches of rubber (on the fat part of the tube). What this does is allow me to get a grip on the fiberglass tube while it is still on the mandrel as I'm pulling the part from the mold. What I want to do is prevent the fiberglass shell from detaching from the mandrel while the part is being pulled out of the silicone rubber mold. This does work well.

However, the final fiberglass part does not have the same shiny surface anymore, because the rubber is no longer shiny. It is still smooth, but not as shiny as I'd like the tubes to be. So I will have to make a new rubber mold for any future tubes that I make **(Figure 7)**.

Figure 7: The rubber was cut off from the mold so that I could grab the fiberglass tube and keep it from being pulled off the mandrel when the epoxy had cured.

Future Enhancements

Why talk about future enhancements if the process is worked out? Because the tubes can always be made better.

When my daughters were using the tubes in competition at the World Space Modeling Championships in Ukraine in 2016, they worked well except in the event of streamer duration. My daughter's completed models

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with the nose and the fins were weighing around 8 grams. This was too heavy for this event - they need to be in the 5 gram range. The models just couldn't catch any thermals, and never reached the max duration of 180 seconds (three minutes). On an "A" motor, the models were only getting half that time. In this event, you have to get the model into a thermal to be competitive.

Therefore the tubes have to be made lighter weight for the streamer duration event.

This is why I started out in Part 1 of this series saying that I'm unsure if using fiberglass tubes for the models is the way to go in order to win. I really don't know, and I'm torn whether I should continue the development of the method using fiberglass, or switch to a different medium. For example, the British team uses laminating film to make tubes, and Jay Marsh makes tubes from thin Kapton sheets.

If I were to continue with fiberglass tubes, I'd have to look for ways to reduce the weight of the finished tube.

I'd start with the tissue paper. Does it really have to be there? If it does, where would I cut out some material? Any tissue paper removed would be a big savings in weight. But then I'd have to worry about the pin holes in the cloth in order to make an airtight tube.

On my tubes, I noticed that the transition part was thicker than the cylindrical portions. That makes sense in that the epoxy isn't being squeeged off the transition by the rubber mold like it does as it slides over the cylindrical sections. I'd have to look for ways to reduce some weight in this area by reducing the amount of epoxy there.

One way is to reduce the thickness of rubber in the silicone mold in the transition portion. I'd have to make a more uniform wall thickness in the silicone rubber mold **(Figure 8)**.

Figure 8: A modified silicone rubber mold with a consistent wall thickness. Compare this to the mold shown in Figure 7.

I'd also try to come up with a way to reduce the amount of epoxy put onto the cloth before it is slid into the rubber mold. Jay Marsh suggested I thin out the epoxy with alcohol. A thinner viscosity epoxy would help it flow better and be squeezed out in the pressure pot. And the alcohol will evaporate out leaving the wall thinner.

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And maybe I'd completely switch to a female mold instead of wrapping around the aluminum mandrel **(Figure 9)**.

Figure 9: A female mold could be used instead of wrapping fiberglass cloth around an aluminum mandrel.

Finally, I think I'd definitely switch to a different epoxy. I discovered that the West Systems brand epoxy that I was using for all my rockets is a very low temperature epoxy. The West Systems epoxy gets soft when it is heated up. That may be why the single layer tubes (without the additional tissue paper layer) were deforming when the ejection charge fired inside the tubes. If the epoxy could withstand the heat by itself, it may be possible to eliminate all the tissue paper inside the tube. That would save a lot of weight right there!

Conclusion

I hope this article helped you demystify the process of making lightweight fiberglass tubes. It has been a big learning process for me to go through, and even with all the mistakes I've made, I don't regret it for a second. It was an investment in my own education, and we did learn how to make tubes that were significantly better than the ones that I made for the previous contest in 2014. And the result is that my daughters did well using the tubes. They were much more competitive against modelers from other countries, and they did help the junior modelers team do the best it has ever done in international competition.

If you'd like to learn more about international competition, see the NAR's web site at: http://www.nar.org/contest-flying/fai-spacemodeling/. They are actively seeking new people to join them, and they have a new mentoring program similar to the TARC mentoring program.

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 a 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 e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact