PEAK OF FLIGHT NEWSLETTER

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PEAK OF FLIGHT

Analysis of Russian and Serbian Ultra Light Model Rockets

By Tim Van Milligan

Imagine a Rockets that is 1.5 inches in diameter and 27 inches long (something in the general size range of an Estes Big Bertha). Now imagine it weighing only 3-1/2 g. This is the Holy Grail in competition rocketry. It is a rocket so light that in a duration event like streamer duration, it has a huge advantage because it would float to the ground like a rubber balloon.

Recently I got to see first hand a rocket just like I described. They were F.A.I. (Fédération Aéronautique Internationale, the governing body for international aerospace records) style rockets, from countries like Serbia and Russia. As an engineer these rockets fascinate me. The amount of engineering and the level of craftsmanship were staggering. They were far better than the best rocket that I have ever made, by at least an order of magnitude. I was simply in awe when I saw these rockets.

Figure 1: Serbian made fiberglass rocket. Notice the smooth surface on the rocket. This rocket weighs around 6 grams. That includes the nose cone and the balsa wood fins.

In this article, I want to note my thoughts on the construction of these rockets. Maybe it will inspire you to share what you know about construction of lightweight competition style rockets.

Unfortunately, some of what you read here may be speculation, because I have never made anything as nice as these models. In other words, I can't really say with 100% certainty what techniques were used to make them.

My own history of trying to make light weight fiberglass tubes for international competition goes back to around 1990, about 26 years ago. At that time I was a launch operations engineer on the Delta II rocket in Cape Canaveral, Florida. My job was to help set up and launch payloads into orbit. But as I walked up and down the stairs of the rocket gantry, my mind drifted to small model rockets. I had an interest in making model rockets more efficient.

I have attended a few NARAMs, and the challenge of competition rockets drew me because it is all about doing things more efficiently. Competition has never been about winning contest, or beating others. In a sense, rocketry is like golf, where you only really compete against yourself. For me, scoring is a measuring stick to see if you are progressing and getting better. That was, and still is my motivation for learning how to build light weight fiberglass tubes.

My first fiberglass tubes were made in 1990 as I got ready for the US team tryouts. The basic methods and materials are still the same today, as they were 26 years ago. The only thing that is different is that back then the rules of international competition called for tubes that were 30mm in diameter. Today they are 40mm.

Construction starts with a metal mandrel. Steel is preferred, but aluminum is cheaper. **Figure 2** (on Page 3) shows a collection of mandrels that I purchased back when I started out. If you would like to get a mandrel for your own work, they are available from the NAR (http://www.nar.org/NARTS/).

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Figure 2: Aluminum mandrels that are used to make ultra lightweight fiberglass tubes. The mandrels are polished so that the final tubes are easier to remove once the epoxy has cured.

I won't go into the construction of the typical tube, because you'll find better instructions at: https://sites.google.com/site/xfaispacemodeling/construction-methods/lightweight-fiberglass-tubes. There is also a good video on YouTube made by Dave O'Bryan and Kevin Johnson at: https://www.youtube.com/watch?v=NYM1B-FqA24M

Figure 3 shows a collection of tubes that I made when I first started out. To be honest, the tube sizes have gotten bigger, but the quality of my tubes hasn't improved much until late last year. I'll illustrate the biggest issues that I have with my tubes.

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Figure 3: A collection of fiberglass tubes that I made over 25 years ago. I save the rejects as well as the good models, so that I have a way to gauge my progress toward achieving a perfect tube.

First, the surface finish isn't that good. You can see that they don't have a mirror smooth finish that you'd like to see for rockets with low drag. Why? Because to make the tubes lightweight, you have to squeeze out and soak up the excess epoxy. This leaves the surface a bit dry, and the layers of fiberglass cloth protrude up through the surface (**Figure 4**).

Figure 4: Because this tube doesn't have enough epoxy, the weave of the fiberglass cloth projects out. This creates a higher skin friction drag than if it were mirror smooth.

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The technique I used in the past was to try to put on the epoxy a little thick and then sand it down smooth. Unfortunately, this causes other problems. First, you can never seem to get the epoxy on in a uniform layer. It turns out thicker in some places than others. So you have to sand extra in some places on the rocket. You've read before how much I hate sanding, right? Because of this I try to take short cuts, and that always seems to have bad consequences. I often end up sanding right through the tube (**Figure 5**). I can't tell you how many tubes I've ruined. But my reject rate is probably 80 percent. Which means I get only two good tubes out of the ones that I started.

Figure 5: This tube was ruined because it was sanded too much. But you can still see a lot of grooves that need to be sanded smooth.

The second problem is small holes in the rocket. This occurs when you remove all the excess epoxy from the tube. If you want a lightweight tube, you have to remove as much epoxy as possible. But when you remove too much, it leaves gaps between the weave of the fiberglass. These holes make it hard to pressurize the tube in order to eject the recovery device at deployment. They also weaken the tube and allow the hot ejection gasses to flow through the cloth. If you don't seal the holes, because of the heat flowing through the cloth, the tubes don't last but one single flight. The heat is the big problem that destroys tubes and causes them to warp. You'll see several tubes in **Figure 3**, **Page 3** that are extremely warped due to heat.

Figure 6: An example of a complex curve. The cloth has to curve around the perimeter of the tube, as well as curve along the axis of the part. It is complex curves like this that are extremely difficult to construct with fiberglass, and even more so with tissue paper.

The next big problem is color. Fiberglass is white, which makes for a rocket that is hard to see against hazy skies. So you have to find some way to add color. You don't typically want to add paint to the rocket, because it is heavy. Therefore, most people will wrap

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a layer of colored tissue paper over the fiberglass cloth while the epoxy is still wet.

Besides adding color, the benefit of the tissue is that it seals up all the little holes between the weave of the fiberglass cloth. Plus it adds a little bit of extra strength.

However, there are a couple of drawbacks to tissue. First, it doesn't go around curved surfaces (like a nose cone) at all. The reason is that the weave is too tight (**Figure 6, Page 4**).

Compare it to fiberglass where the cloth fibers are free to slide around in the weave. This allows it to conform to tight curves. In paper, the individual paper fibers are fixed in position and don't slide around easily. Because of this, tissue can be applied only to cylinders and conical sections. If the cone has any curvature, it is going to bunch up and leave a lump. This will have to be sanded out later. Of course, as soon as you sand the tissue paper, it removes the color. Now you have gaps in the color of the rocket. It just looks unprofessional (**Figure 7**).

Figure 7: Because of the creases in the tissue paper, there were bumps in the finished part. When these were sanded smooth, the tissue paper was sanded away too. While smooth, the part looks bad.

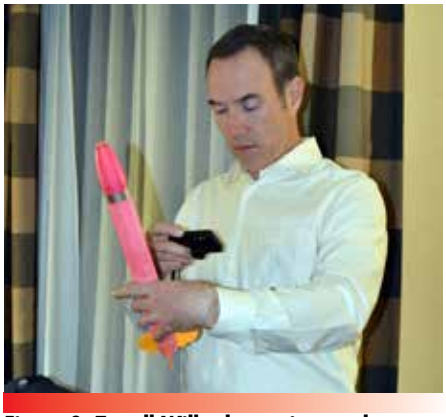

Figure 8: Terrell Willard examines and photographs a Serbian made rocket tube. You can learn a lot by studying the works of other modelers.

The big problem I've struggled with using tissue paper, is that it is never perfectly smooth. It always seems like it has a crease in it. The crease never sticks down to the fiberglass beneath it. The only way to get it to stick is to put it under the fiberglass. This works fine, but now you don't have the smooth surface of the tissue paper on the outer side of the tube. You end up with the weave on top.

The final problem with the technique of wrapping fiberglass over a mandrel to make a tube is the process of removing

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the cured part from the metal mandrel. The tubes are so thin and so fragile, that they can't be man-handled too much. If you over stress them, you can easily split or tear the tube. I bet most of my 80% reject rate comes from trying to remove the tube from the aluminum mandrel.

Figure 9: Close up view of the Serbian transition. The surface is so smooth that it shines.

Figure 10: An example of a two-part female mold used to make fiber-glass nose cones.

Figure 11. The cloth is laid into each side of the mold. The cloth was painted with florescent paint to give it some color.

The key is to find a good release agent under the fiberglass/epoxy so that the tube will slide easily off.

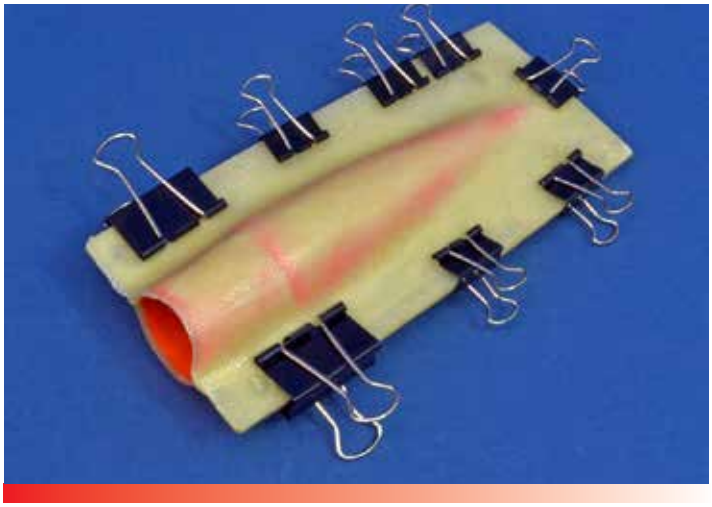

Figure 12: The two halves of the mold are clamped together while the epoxy cures.

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However, I have to admit that I'm still searching for the perfect mold release. In the past I used a spray on wax. The advantage of this is that the whole mandrel can be heated in an oven or hot water, which melts the wax. The melted wax acts like a lubricant and the tube can slide easily off. However, due to environmental regulations, the maker of the spray-on wax changed the formulation. It no longer goes on smoothly. It now goes on in lumps. That means the fiberglass doesn't lay on smoothly either.

The other thing to worry about is the heat needed to melt the wax beneath it. As mentioned previously, heat also softens the epoxy. And the thinner the wall of the tube, the more the heat seems to affect the epoxy. You have to get the tube off the mandrel, and then immediately put it back on so that when the epoxy cools and hardens, the tube will retain its shape. I've got lots of tubes that are deformed because of the heat applied to remove them from the mandrel.

Figure 13: The seam line can be seen in this close-up view of the rocket tube from Serbia. Because the tube is translucent, you can also see where the fiberglass overlaps on the inside of the tube.

What I'm personally playing with now is a silicone based mold release. It shows some promise, but I still have to work out the logistics of how it is applied, and how the tube is removed from the mandrel. This may not make sense if you've never made a fiberglass tube before, but there are a lot of processes you have to work out. It isn't just the materials and tooling, but the sequence and the techniques seem to matter a lot in making a usable tube.

The Russian and Serbian Tubes

When I examined the tubes made by the modelers in both Russia and Serbia, the thing that jumped out right away was that they were not laid up over an aluminum mandrel. They were made by placing fiberglass in a female mold. This is very similar to the way high-power nose cones are often constructed (**Figures 10-12, On Page 6**).

The two telltale signs of this were that the tubes had two seams running down the opposite sides of its length (**Figure 13**), and that the inside of the tube was not smooth. It was a little bit lumpy. Again, if you've ever seen a hand lay-up fiberglass nose cone, this will be familiar to you (**Figure 14, Page 8**).

So all this time, I was making tubes in a completely different manner than modelers in other parts of the world. And to be honest, I felt like a fool, because it makes so much sense to make them in a two-part female mold.

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Figure 14: The inside of the tube of the rocket from Serbia. You can see that the surface on the inside is not as smooth as the outside. But it isn't as rough as you'd expect from raw fiberglass.

There are a few advantages of laying the cloth in a two-part mold. First, other than the seam on both sides of the tube, the outside of the tube is perfectly smooth. Mirror smooth, in fact. The epoxy always lies against the mold surface, and since the surface is on the outside of the part, the tube is very smooth.

The other advantage is removing the tube from the mold. Since the mold splits in half, the part can be removed easier.

Also, once the fiberglass cloth is played into the mold, it can be painted with a little bit of spray paint for coloring. And these were beautiful. There was no tissue paper at all on these models. They were fiberglass and epoxy only.

The only disadvantage is that the inside of the tube is not perfectly smooth like the outside. However, the inside of the tubes from the Russians and Serbians are not as lumpy as you'd see in a high power nose cone. So they are doing something during the process to smooth them out. It might be that they are putting a balloon inside of the tube and inflating it so that it presses everything tighter against the surface of the mold. This is speculation though, as I haven't seen how they do it.

Now the Russians did one thing better than the Serbians. They made an ultralight weight model out of graphite cloth instead of fiberglass cloth. The result was a weight reduction of nearly two grams. These graphite/epoxy models were in the range of 3 grams, which included the nose cone and the fins. I'm not sure how they made these all-black rockets, because they used a felt-like graphite cloth instead of a woven material. I've worked with graphite in the past, and it is very stiff. How to get it to make multiple curves, like in a nose cone is at the limits of my comprehension. I'd really like to see how they made these beautiful models.

Figure 15: The Russian made graphite/epoxy tube. This entire rocket weighs less than four grams, even though it is nearly as large as an Estes Big Bertha rocket kit.

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I'd also like to find out what mold release and other techniques they are using to make the rockets. I'm sure the logistics of manufacturing them is just as important as what materials and tooling they are using.

The main disadvantage of these ultra lightweight rockets is they are extremely fragile. We surmise that they can't be launched off a piston like other competition models. They would buckle under the launch stresses. But since they are so light, they are going to take a long time to descend back to the ground. And in a duration event, that is more important than how high they boost.

Figure 16: Close-up view of the engine mount and fins on the Russian rocket. You can see by looking at the cloth that the fibers are in a random direction and it is not a weave like a fiberglass rocket.

The other disadvantage is the black color can make them hard to find on the ground. The color would blend in to the dark patches of dirt and shadows on the ground. You really depend on finding the streamer to find out where the rocket landed.

Conclusion

The point of this article was to reverse engineer rockets that are better than what I can build myself. This is part of the process of getting better and helping other modelers to increase their skills too. The learning never ends, does it?

I learned a lot about how to make great rockets from studying the models created by better craftsman than I. It is humbling to find out how far behind them I am, but it also motivates me to become better. And what I find out, I'll share with you in a future newsletter.

My current research has gotten me closer to the Serbian rockets, although my techniques still revolve around the use of wrapping cloth over a metal mandrel. I've since started wrapping the tube in a silicone rubber mold to get a nicer surface finish. It is promising, but eventually I'll have to switch to a female mold to try to get to the same level of quality that I'm seeing in both the Serbian and Russian models.

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.