Apogee Components

PEAK OF FLIGHT

NEWSLETTER

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How To Make Advanced Composite Fins Part 2

Cover Photo: Nike-Hercules rocket stands behind rocketeers at NARCON 2013 near San Francisco, California.

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Advanced Composite Fin Build Part 2 of 2

By Daniel Cavender

At the end of part 1 (www.ApogeeRockets.com/Education/Downloads/Newsletter332.pdf), I listed the lessons I learned from developing a new way to layup a fiberglass fin. The mold was small so only one fin could be made at a time. I learned that there was a good deal of variability between the three fins I made. The flattened creases were all different sizes and the resin to fiberglass ratio varied with each layup. I wanted to layup multiple fins at once and reduce the variability between them. Aligning the mold halves properly was a small struggle, and when working with epoxy, time is working against you. I wanted aligning the mold halves to be thoughtless. After laying up three fins, the MDF mold was beginning to show signs of deteriorating. I wanted a mold to last longer.

I made a second mold that was 24" long and 6" tall. The new mold has alignment pins along the bottom to perfectly align the two halves. Then I coated the mold several times with spray-on Shellac. I used a 24" section of 2.6" Airframe to complete the three piece mold. I epoxied spare centering rings and bulk plates inside of the airframe to help it keep its shape better when under compression. And to make the layups a little easier, I bought a roll of 12" wide fiberglass tape. The ends are stitched so they don't fray which was really easy to work with, but I'll get to that part soon. First, I want to tell you about how I made the bigger mold.

Figure 1: The basic parts needed to make molded fins.

Building the New Side Molds

I built the new side molds much like the old. I first cut four 24" x 6" MDF pieces. I again sanded off any frayed edges around the corners to prepare them for gluing. Again, the new mold will be four MDF pieces thick. Each side is made of two pieces of the MDF glued together. I again spread a thin layer of Gorilla glue across the entire surface of the faces to be bonded. This time, I used a wooden tongue depressor to work the glue around in a thin film on the much larger bonding surface. It's very important that the two halves not be glued together. I flushed up the edges and used four bar clamps to compress the MDF parts while the glue dried. I wiped the excess expanding gorilla glue off of the sides. Once it was dried, I cleaned up any remaining dried Gorilla glue, leaving the whole assembly clamped together.

With the mold still clamped together and the edges all still flush, I went to my drill press and drilled three ¼" holes in the mold for the alignment pins. The two outside holes were 1" from the outer edge of the mold and 1" above the bottom edge. The middle hole was 1" from the bottom edge of the mold and at the mid-point (12" from either edge) of the mold. I removed the clamps, cleaned any MDF from the holes, and carefully glued in a ¼" dowel pin halfway into the three holes on one side of the mold only. These alignment pins will fit into the match drilled holes on the other mold half, and presto! The mold halves will now easily align together so I don't have to fuss with it later.

I learned on the first mold that I would need a spacer between the two mold halves before I drew on the airframe's curve. I'll illustrate why in Figure 2. On the left is the way I drew the line, and on the right is the way the curves would look when the molds have 10 plys of fiberglass wedge between them. The curves no longer align. The

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gaps are right at the top and at the bottom, but you can see that the gap is bigger in the middle of the curve on both halves.

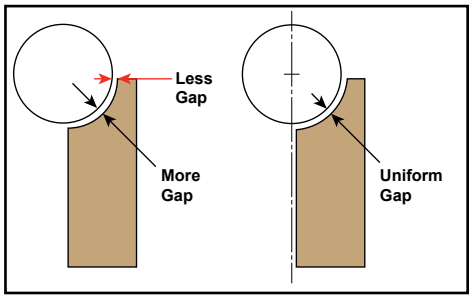

Figure 2: Compensate for the fiberglass thickness when drawing the circle on your MDF mold halves.

I needed to put a spacer between the two mold halves to compensate for the curve distortion, so I added a few slips of scrap G10 from fins or bulk plates. I then placed the edge of the airframe tube on one side of the mold, centered it up, and sketched the curve of the airframe. Now I know that I will get the curve I want.

Figure 3: Sanding the mold to match the curvature of the tube.

Instead of cutting this curve out with a table saw, I clamped the mold into the vice on the deck of my mill and used a 1" ball nose end mill to notch out the curve, working the end mill across and down until I was on the curve I drew earlier. I kept one hand on the table wheel and the other on my Shop-Vac sucking up the chewed up MDF as I went. Next I clamped the mold to the edge on my work bench leaving the G10 shims between the mold halves. Alignment was a synch because of my great new alignment pins.

Then for the next 30 minutes I sanded the curve smooth, stepping the sand paper grit down from 120 to 220, and finally 330 as seen in Figure 3. I unclamped the mold and pulled the two halves apart. I cleaned up all of the corners and sanded a tiny fillet on the inside edge of the curve on both mold halves just like I did on the first mold.

I wiped the mold down with a rag and some alcohol, and once that dried I sprayed the mold with several coats of Shellac to seal and protect the MDF. It took a lot less time to make the second mold than the first since I had a better idea of what I was doing. There really is no substitute for experience.

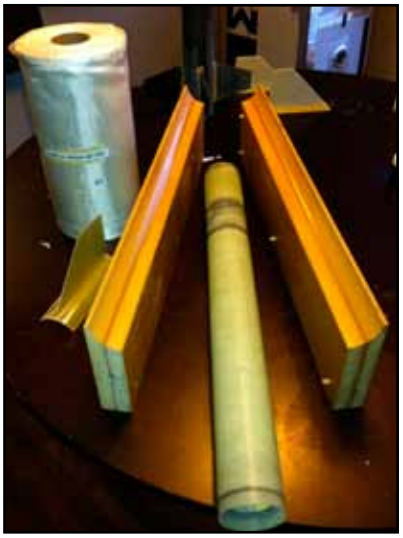

Figure 4: The completed mold halves.

Preparing The New Mold

Mold preparation was easy. Again, I needed a cutting mat,

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razor knife or scissors, straight edge, a roll of 19" wide Dura-Lar, and some clear Scotch tape. First, I cut a 26" long piece of Dura-Lar which would lay full length down the mold sandwiching the fiberglass between. I cut and rolled a piece of Dura-Lar around the 24" segment of airframe and secured it with a few pieces of Scotch tape. I also applied a light layer of partal paste wax to further protect the mold from resin. Done!

Fiberglass Prep and Layup

This is the easy part. To make one fin, you will need:

- Two-part epoxy resin system (West, US, Aeropoxy)
- Digital scale
- Mixing cups & stir stick
- Latex/Nitrile gloves
- Five 24" long strips of 12" wide fiberglass tape
- Plastic drop cloth to cover work area

I covered my work area with two layers of plastic drop cloth and laid out the work supplies. First I weighed the 5 fiberglass sheets on the digital scale. The fiberglass weight about 4 oz., but I learned that I did not need to mix a 1:1 ratio of epoxy to fiberglass weight. I instead mixed 3 oz. of resin. Waste not – want not. Just like before, I fully wetted one sheet at a time, using a short round wooden dowel to work out as much of the resin as I could, stacking the next sheet on top of the wetted ones as I went. When finished, I had an ideally wetted fiberglass sheet ready for the next part of the build. I folded the wetted fiberglass in half, matching the ends and pressing them flat as I worked my way to the crease. Be careful not to press the crease flat. This part will be pressed into a curve surface that matches the airframe.

Molding the Fin

This part took a little more time to get right than the smaller mold. 24" of wetted fiberglass cloth likes to stretch and droop. I positioned the fiberglass between the two side molds draped in Dura-Lar with the creased end protruding out in the middle. I pressed the two side molds together, sandwiching the fiberglass in the middle, engaging the alignment pins, and clamped them together loosely.

As before, the crease will be pressed flat against the curve's surface, so make sure that the crease when pressed flat will yield a symmetric surface. Imagine that the crease is a tube, and you want the tube to be the same diameter along the full length of the mold. If it is not, the flattened surface will not be symmetric. Once I got the crease aligned to my satisfaction, I tighten the clamps to secure the fiberglass from moving.

While building the first couple of fins in part 1, I noticed a gap between the fiberglass cloth that ran almost the full length of the fin's root chord. The volume was void of fiberglass and resin. I want to get rid of that gap and have a solid laminate. What I discovered was that I could pull some fiberglass filaments from a free edge of a fiberglass

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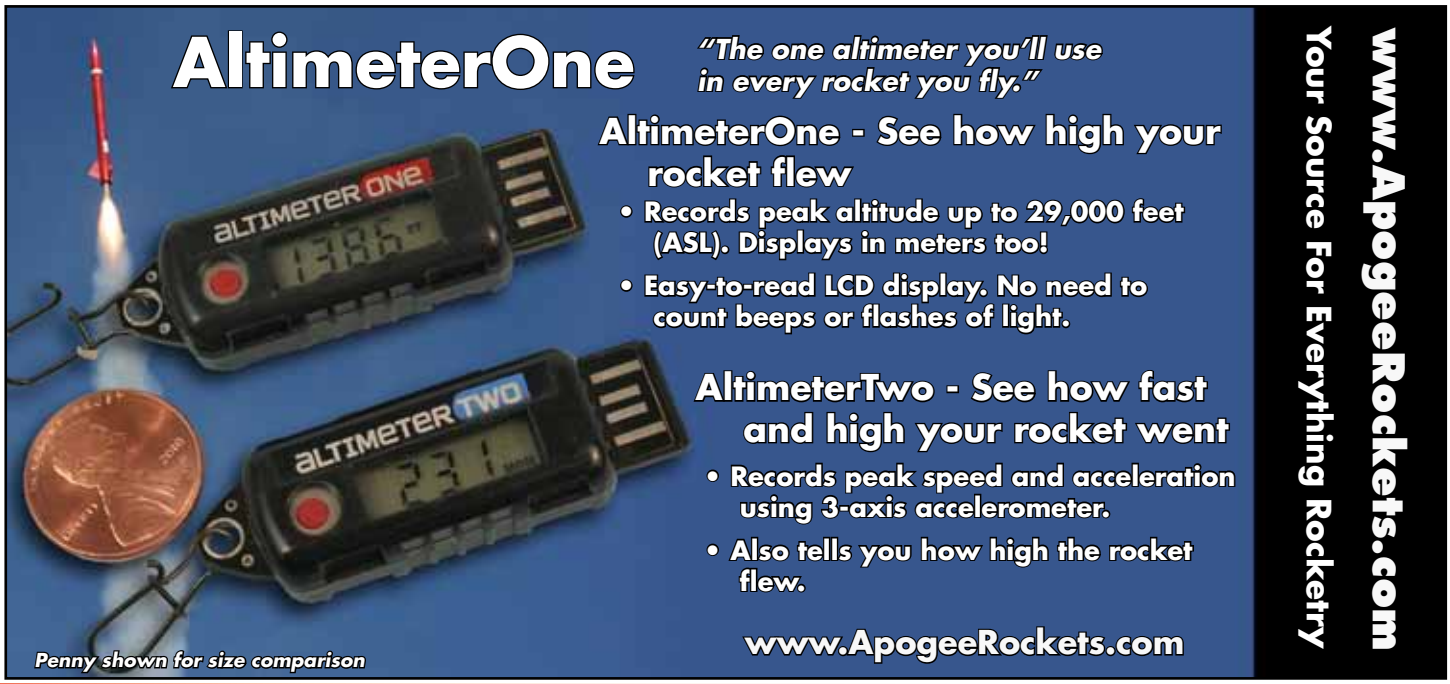

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sheet long enough to reach from one end of the mold to the other (24" at least) and bundle them together to about the thickness of a coffee stir straw, and wet them out then feed them through the crease in the fiberglass layup before I flatten it. I worked the bundled wetted fiberglass filaments down into the saddle of the fin root to fill the gap. It took a little effort and skill to get it through, but it did the job. I then placed the Dura-Lar wrapped airframe segment down onto the crease, pressing it flat. The fiberglass should be evenly split left and right of the centerline. Rotating the airframe tube slightly can achieve the necessary symmetry.

Once the fiberglass was laid out the way I wanted it, I used some duct tape to hold the airframe tube down in place. The layup was finished. I placed the whole assembly into my preheated oven and let it begin a nice long cure process. I put some plastic down in the bottom of the oven to catch the excess resin that was squeezed out, and baked the layup overnight at around 120 degrees.

The oven I built is 36" X 18" X 18". I was able to achieve a maximum temperature of 120 degrees using a 60 Watt light bulb. Not the fluorescent kind, but an old fashioned incandescent one.

Figure 5: Curing the epoxy in a oven box made from aluminum-foil lined house-insulation.

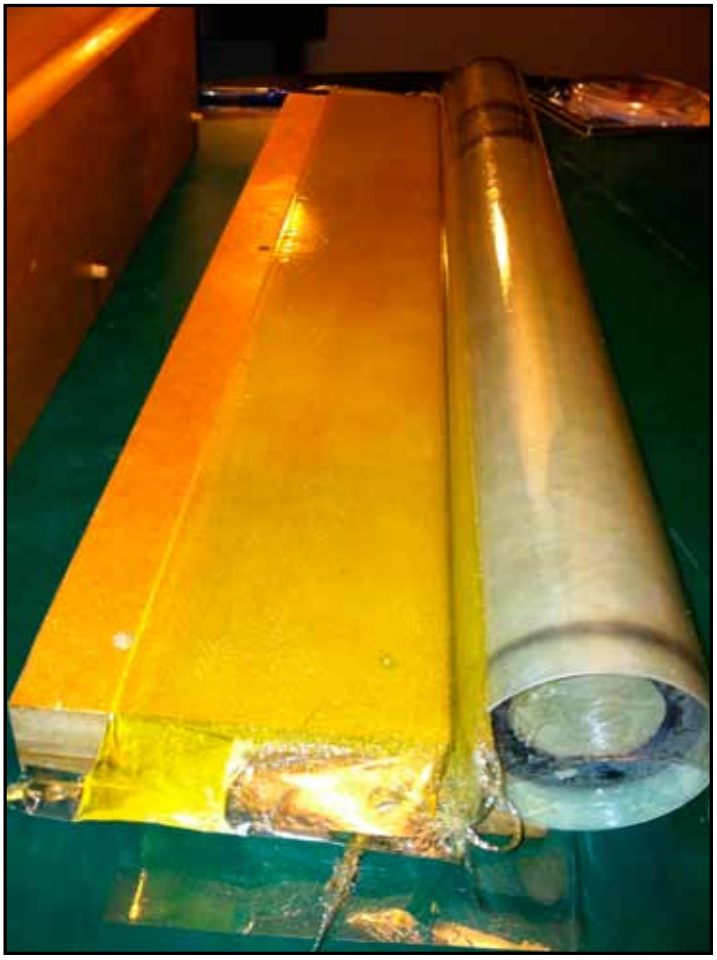

Figure 6: Fiberglass strake partially removed from the fin mold.

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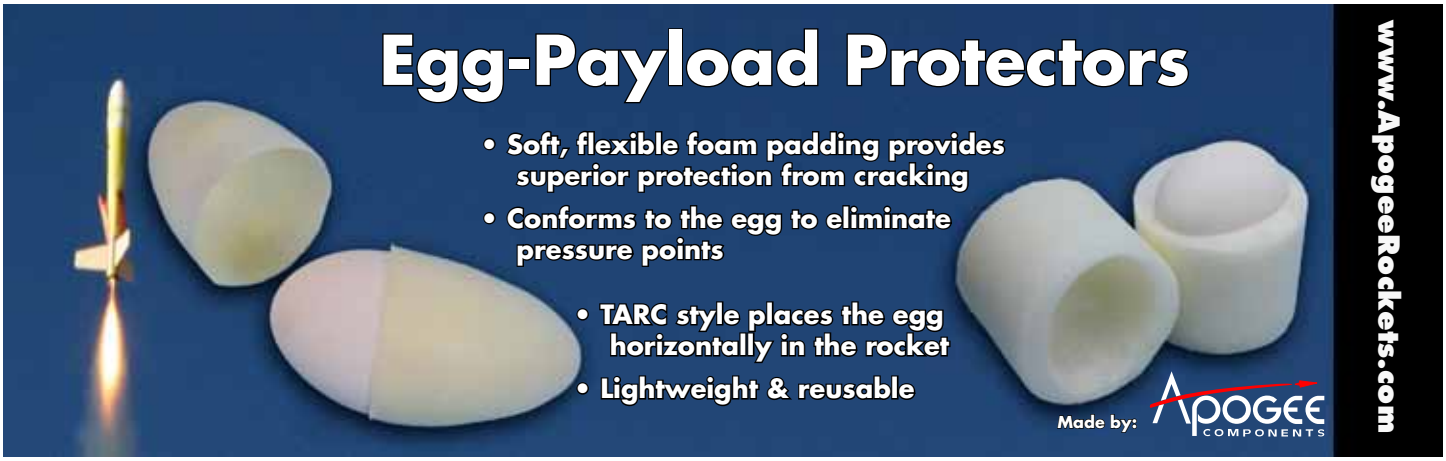

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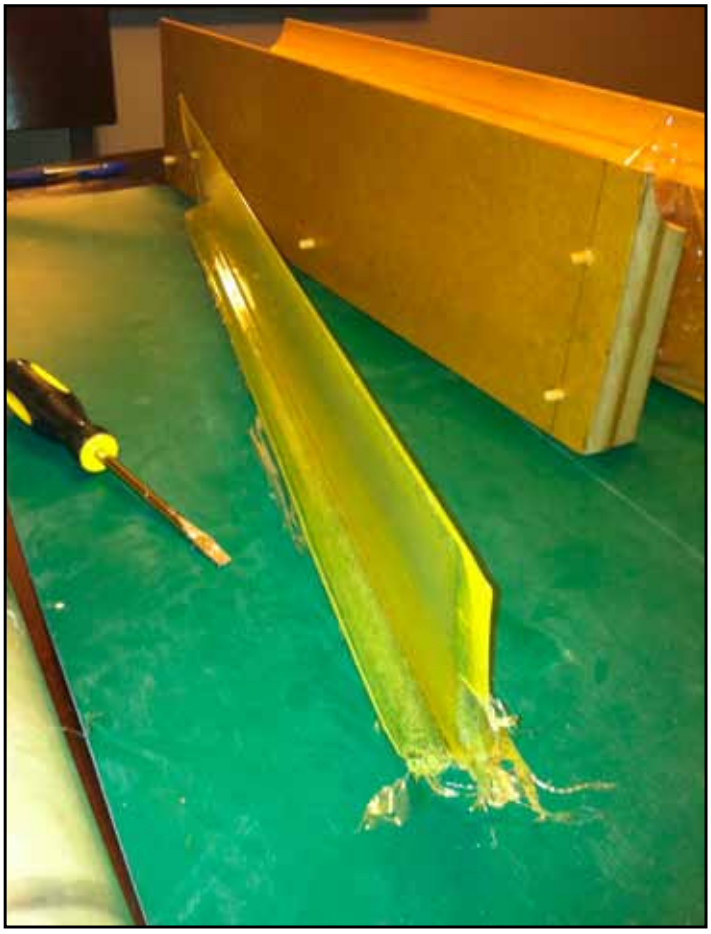

Figure 7: Fiberglass strake fully removed from the fin mold.

I started the part in the oven just before I went to bed around 11 PM, I tuned the oven off just before I left for work around 8 AM. When I got home that afternoon, I started to deconstruct the mold. I removed the bar clamps and lightly pried the mold halves apart by inserting a flat head screw driver in the gap along the bottom until the alignment pins released. The Dura-Lar peeled off easily and I was left with the raw fin stock. Now it was time to make some fins.

Cutting the fins

I had a specific fin design in mind that I wanted to make

Figure 8: Cutting the fins to shape was done on a table saw using a jig to hold the fin level.

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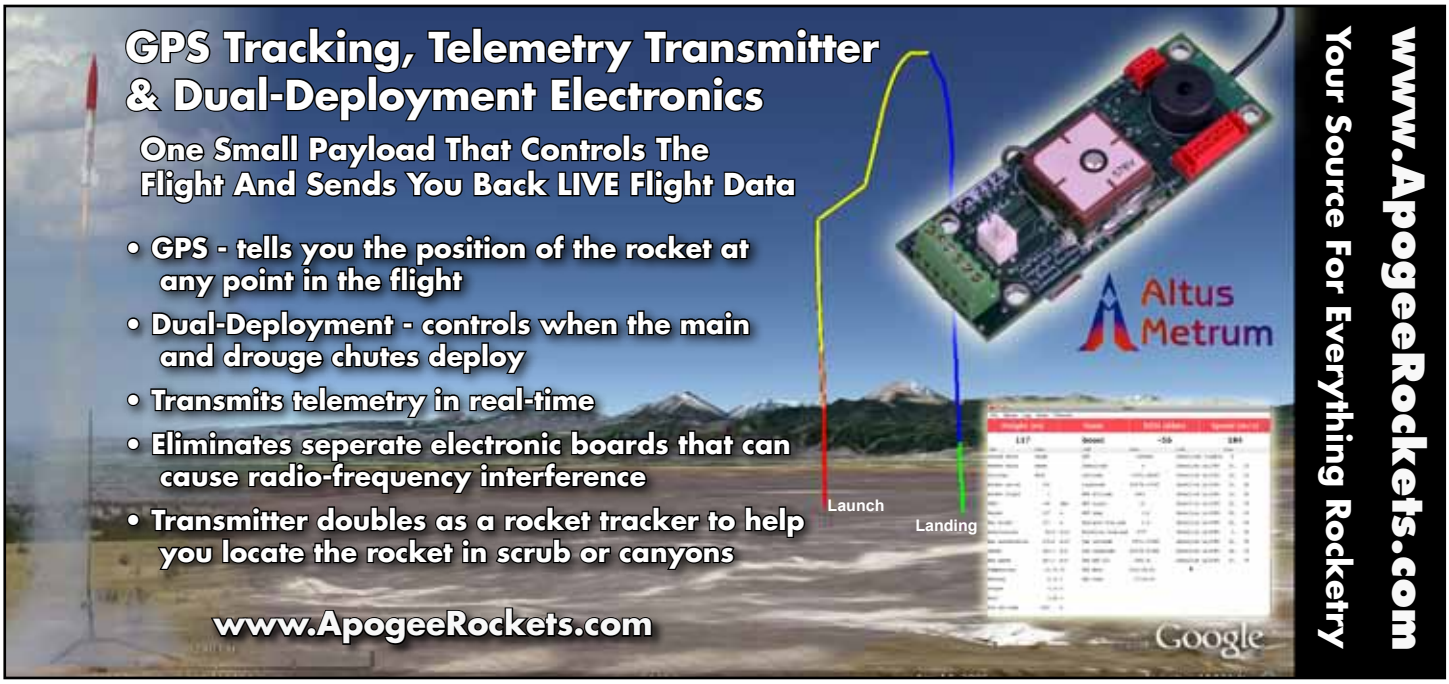

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this time. The only edge that I know for sure is true is the inside fillet at the root chord of the fin. I couldn't lay the fin flat on the table saw's deck either. I needed some way to hold the fin level with the deck and alight the fin root with the table saw's fence so could cut the tip chord. I build a jig to grip the whole fin layup using the inside fillet as the reference so I could cut the tip chord using my table saw. It wasn't easy coming up with the idea, but I hope that Figure 8 helps explain it. It worked very well.

Cutting the rest of the fin was much easier now that I had a good edge to reference the rest of the cuts. I measured and marked the fin points onto the fin stock, and carefully cut the leading and trailing edges for each fin. I sanded a symmetric chamfer on leading and trailing edges of the fin and lightly sanded the surfaces to prepare the fins for bonding and painting.

I cut the bonding surface (the curve bottom side of each fin) to 1" wide using my manual mill machine. I could have done the same thing on my table saw with a jig. I gripped the fin upside down in my table vice and used 4 fluted ½" end mill to trim the fin bonding area equally on both sides. That was very handy in getting a good symmetric bonding surface.

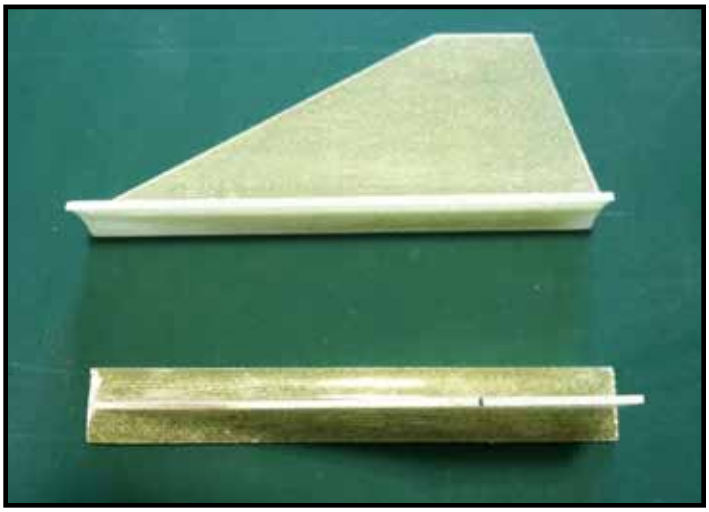

Figure 9: The fins were cut to their final shape.

Minus the cure time in the oven, the whole task from beginning to end took just over an hour once I built the mold and jig. Bonding the fins to the airframe took minutes. The whole task takes some practice so don't get frustrated if you don't get a perfect product the first time. I am still developing the technique also, but I found that this method opens an exciting new area of composites and rocketry for me to explore.

Surface Bonding Fins

So this is what it has all been for. All that work and practice making surface mounting fins builds to this moment. Epic, right? Anyway, this part is pretty straight forward. The bottom surface of the fins are contoured to the surface of the airframe, so alignment is very easy. I'm going to focus on good practices for a clean and strong epoxy bond.

I began with surface preparation. The Dura-Lar left a smooth and glossy surface finish on the fin. We need to get rid of that on the bonding area. As shown in Figure 10, I rolled a sheet of 150 grit sand paper around the airframe that I am going to

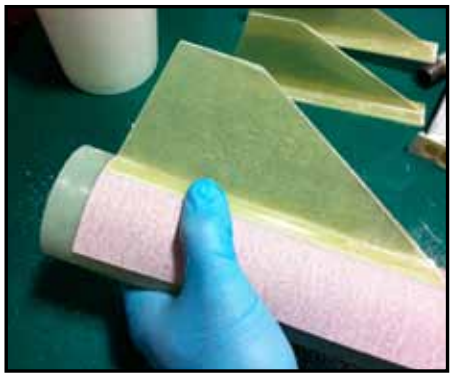

Figure 10: Sanding the bottom to roughen up the surface.

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bond the fin to, and I slid the fin back and forth until the fin's bonding area is a nice dull finish. I turned the sand paper on the airframe and lightly sanded the area where the fin will be bonded. I thoroughly cleaned both airframe and fin bonding areas with acetone and a paper towel.

I want to put four fins onto the rocket, so I marked the "clocking" for the fins on the bottom of the airframe. I applied epoxy to the bonding area of the fin. I used my finger to smear the epoxy into an even layer. I like to use 3M's DP-420 2:1 epoxy. It's pricy, but it has great bonding strength and the application gun and disposable mixer nozzles make it extremely convenient. I placed the fin onto the airframe and slowly but firmly worked it around just a little to work out any air bubbles in the bond area. I bonded one fin at a time allowing each fin to cure in place before I moved on.

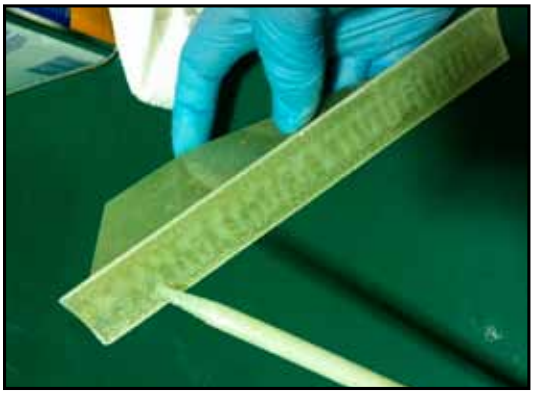

Figure 11: Applying epoxy to the root edge.

I was very happy with the way that these fins turned out. There was an industrial quality to them that made me feel kind of good too. I've been around a lot of military missiles and even a few NASA sounding rockets. I always liked the bolt-together assembly line quality to them. I'm headed off this weekend to fly the first rocket built with these fins. When I get back, I'm going to start upsizing this process and developing fins for 4" airframes. Find the Huntsville Area Rocketry Association's Facebook page and find out how it went.

Lessons Learned from Fin Molding

1. There was a good amount of resin that was squeezed out of the mold. I want to optimize that resin/fiberglass ratio. Vacuum infusion may be a solution.

2. There were bubbles in the resin matrix that did not cause any problems, but I want to make better fins in future layups. I will try a vacuum system to infuse the resin into the fiberglass. Once the fiberglass is fully wetted, I will remove it from the vacuum bag and begin the molding process.

About the Author

Daniel Cavender is a leading researcher in nuclear thermal propulsion at NASA's Marshall Space Flight Center, and subject matter expert in the realm of amateur rocketry. He is president of the Huntsville Area Rocketry Association (HARA) and has contracted with the Alabama Space Grant Consortium (ASGC) to conduct advanced rocketry workshops for NASA student launch initiative program. Daniel holds a level three certification with both NAR and TRA, and is a member of the TRA Technical Advisor Panel. Daniel encourages students to pursue science-oriented careers through hands-on experience, and promotes sport rocketry for all ages.

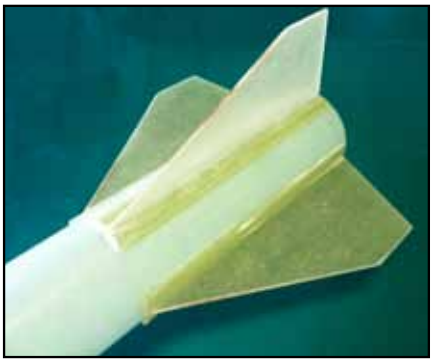

Figure 12: The finished fins bonded to a fiberglass tube.