PEAK OF FLIGHT NEWSLETTER

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BASICS OF VACUUM BAGGING FINS

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PEAK OF FLIGHT

Basics of Vacuum Bagging Fins

By Tim Van Milligan

If you need a fin with some specific properties like having a super-smooth surface finish, being exceptionally lightweight and also ultra strong, then you might want to consider the process of vacuum bagging them. It typically isn't a process you'd use often, but knowing this skill can get you past some difficult situations in rocketry.

First of all, this article will cover the situations when you might want to use it. It is not something that most rocketeers will use. If you do decide it is worth it for your project, then we'll talk about getting your feet wet with the process, using the bare minimum equipment in order to keep the costs down.

Full disclosure: I only started vacuum bagging fins last year, so my experience level is not as great as other people have. In my case, the fin I needed was for an FAI competition rocket. I needed all three variables (weight, surface finish, stiffness) to be maximized.

Typically, when you have a situation where there are three variables, the guy making or selling them to you will say: "Pick two out of the three… you have to decide which one of the variables you can live with not being optimized." In my case, I couldn't sacrifice any of those qualities.

There is a fourth variable in this situation too, and that is "cost." How much would it cost to make these fins that have to be super optimized? We should probably know that first, before we talk about when you might want to use it. What I found out during this process is that other than the up-front equipment cost, the actual cost added to optimize the fin in the other three variables was relatively low. That's good news.

But what equipment is needed? Again, if it is going to be a challenge to get the equipment, then you might want to consider other options for achieving your rocketry goals. I'll start out by giving a general overview of the stuff, but know that at the end of this article, you'll find the list and some suggestions on where to purchase them.

The biggest and most costly piece of equipment is a vacuum pump. They are relatively common, and can be found at Harbor Freight or online retailers like Amazon. I was fortunate in that I had a small reed-type air brush air-compressor that was just sitting around collecting dust. While it was designed to blow out air, I simply connected the air intake side of the compressor to the vacuum bag. I was pleasantly surprised that it worked quite well as a vacuum pump, so I didn't have to buy a new one.

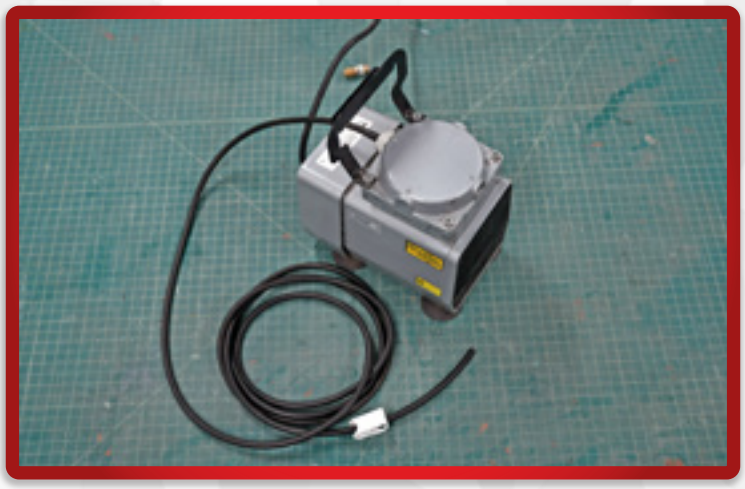

FIGURE 1: VACUUM PUMP WITH NEOPRENE TUBING

Once you have a pump, the other equipment you'll need is pretty affordable because it is small stuff.

1. You'll need a special fitting called an **EZ-Vac Connector** that allows you to connect the hose from the vacuum pump to the plastic bag that the part is slipped into.

2. **Breather Cloth:** This is used to keep the sides of the plastic bag from touching each other once the vacuum is applied. Wherever the plastic sides touch, air cannot flow through, and you won't be able to pull out any air bubbles stuck on the surface of the fin. The breather cloth looks like felt, but the stuff I buy is made from plastic. The advantage is that it doesn't compress as thinly as a felt fabric would, so it allows the air to flow through a little better. In a pinch, you can use something like a few layers of paper towels as a substitute.

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3. **Quick Lock Seals:** These are long extrusions that allow you to quickly seal the open end of the bag so that it is airtight. I think these are so convenient that it is a must-have item.

4. **Neoprene tubing:** This is the tube that connects to the vacuum pump and the fitting on the plastic bag. The main criteria is that the tube has to be rigid enough so that it doesn't collapse under a vacuum. If it does, then air won't flow through it so you can suck the bag down tight against the part.

5. **Pipe to hose fitting:** This is the fitting that you'll use to connect the vacuum pump to the hose. The exact one you'll need to get will depend on the screw fitting built into your vacuum pump. This may be the hardest to find accessory that you need.

6. **Tubing Clamp:** This is an optional piece of equipment. What it does is to pinch the tubing closed, so that air can't pass through it. The clamp will allow you to turn off the vacuum pump once the bag has been sucked down tight. However, I've found that they don't seem to be perfect, and eventually air leaks back into the bag when the pump is turned off. So I typically just leave the pump running until the epoxy is hard.

7. **Plastic Bag:** I used a regular polyethylene plastic bag with good results. Thicker plastic seems to be easier to work with because it doesn't bunch up as much as you're sucking the air out of the bag. I had some 6-mil thick plastic bags that we use to package up high-power rocket kits. That seems to work well. The smoothness of the bag will be the smoothness of your final surface finish of the fin. So try to find shiny plastic if possible.

FIGURE 2: EZ-VAC CONNECTOR IS ATTACHED TO THE PLASTIC BAG SO THE AIR CAN BE SUCKED OUT OF THE BAG.

FIGURE 3: BREATHER CLOTH ALLOWS AIR TO FLOW BETWEEN THE SHEETS OF PLASTIC AND OUT OF THE BAG

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FIGURE 4: QUICK-LOCK SEAL WILL CLOSE OFF THE OPEN END OF THE BAG SO THE PLASTIC IS AIR-TIGHT

FIGURE 5: TUBING CLAMP TO PINCH OFF THE FLOW

In vacuum bagging, we're almost always using epoxy on the surface of the fin, and the goal of the process will be to smooth out the epoxy and give us a uniform surface finish. This was what I was doing when I was making the lightweight fins for the competition rockets. I only used epoxy to skin over balsa wood fins.

But you can also use this same process for bonding skins to the surface of the fins as well. This is how it is normally used, because it will greatly increase the strength of the fin. The stiff skin provides the structure since it is more rigid than the balsa wood.

Some types of skin materials that have been successfully used are: tissue paper, fiberglass cloth, carbon fiber veil or carbon fiber cloth.

Tissue paper is the weakest, but it is "plenty strong" for competition rockets if you need more strength. An advantage is you can get it in colors, so it provides decoration as well as stiffness.

Fiberglass cloth and carbon fiber are typically used for higher power rockets where you really need a lot of extra strength that you can't get from ordinary balsa or wooden fins. It will add some serious strength to your fins, which you may need for models going supersonic that tend to flutter and shred. Carbon fiber is significantly lighter weight than fiberglass, but it is more expensive. The advantage of a woven cloth from either material is that it can conform to a compound curve. So if you have an airfoil sanded into the wood underneath, the cloth will follow the curve nicely without having to fold over itself. Tissue paper doesn't conform, since it can't reorient its fibers easily, and will have a crease in it if you lay it over a compound curved surface.

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Why Vacuum Bag a fin?

What the vacuum bagging process does is to smooth the epoxy out so that it has a more uniform thickness and a better surface finish. This is particularly useful when applying a fiberglass or carbon fiber skin to the fin, because it can be difficult to avoid air bubbles trapped under the cloth. If you have a gap of air under the skin, then you lose all the advantages of putting on a skin to increase fin strength. Vacuum bagging is a way to suck those air bubbles out while the epoxy is still wet, so the skin is really laminated to the surface, and strength is maximized.

I repeated the goal of vacuum bagging, so you don't assume it can do something that is not possible. Most people think that the vacuum bagging process will squeeze out as much epoxy out of the cloth as possible. In my experience, that is not what it does. If you put too much epoxy into the cloth or onto the surface of the fin, it doesn't squeeze it all out.

I read somewhere and unfortunately I can't find the source that vacuum bagging is equivalent to putting a max of 8 psi of pressure on the surface. So think of it like putting some heavy weights on the fin to smooth out the epoxy on the surface of the fin. Unfortunately, 8 psi isn't all that much for squeezing out excess epoxy.

If your goal is to squeeze out all the excess epoxy to make it as light as possible, what you really want to do is put your fin in an autoclave (a pressure chamber that also adds heat to speed up the cure time). That's what they do in the aerospace industry. I've also done it for fiberglass tubes (https://www.apogeerockets.com/education/downloads/Newsletter434.pdf), but it was a hassle.

My pressure chamber was only capable of about 20 psi of pressure. But it is certainly better at squeezing out epoxy than the 8 psi you'd get from vacuum bagging.

Other than the situation where you're attaching fiberglass or carbon fiber cloth skins for extreme strength, the technique isn't used a lot in rocketry because it is rare that you couldn't achieve the same results with other finishing methods; particularly if you don't need to optimize three variables (weight, surface finish, and strength) all at the same time.

In my situation, where I found vacuum bagging useful is fins with airfoils (compound curves). I was looking for a glass-smooth surface finish without having to paint it. This is possible because the plastic of the bag can stretch a little bit to follow the curvature of your airfoil, smoothing out the epoxy nicely.

The Process of Making Competition Fins with a Smooth Surface

You want to start out with fins that are pre-airfoiled and as smooth as possible. In the fins that I was making for competition rocketry, I was using low-density 1/32-inch thick balsa wood. Even 1/32" thick wood was too thick, and I had sanded it down a lot thinner than that to lose even more mass.

Then I sealed the surface with wood filler. All the little grooves and valleys in the surface of the wood have to be filled, or the epoxy would eventually fill them. Epoxy is heavy, and if weight is critical, then they should be filled with something that has a lower density. That is why I chose to use wood filler initially to seal the fins, because it has lower density.

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FIGURE 6: A THIN BALSA WOOD SHEET THAT WAS FILLED WITH LIGHTWEIGHT FILLER TO MAKE THE SURFACE AS SMOOTH AS POSSIBLE.

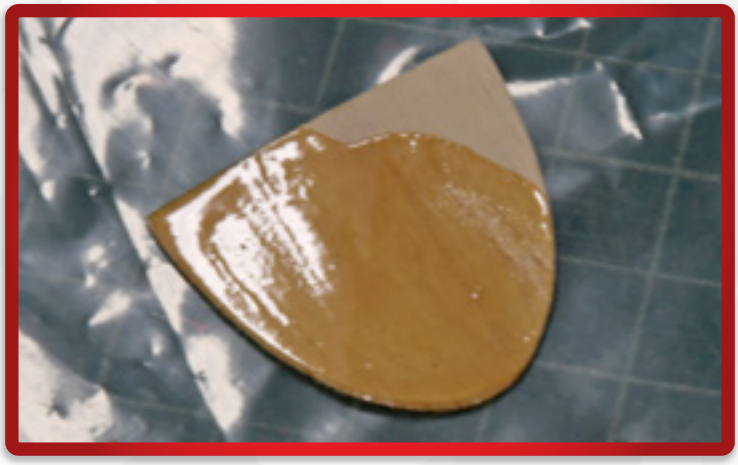

FIGURE 7: THE FIN IS COATED ON BOTH SIDES WITH EPOXY.

So essentially, the fin I was going to cover with epoxy was already filled and smoothed like you would with a typical rocket just before you paint it.

The difference between covering the fin with paint versus epoxy is that the epoxy is a lot stronger and less brittle than paint. So it adds strength to the fin, where paint really doesn't. In this competition rocket, the fin would be unpainted in order to keep the weight down to a minimum. My personal goal was to have the fin weigh about 0.2 grams (with the epoxy skin on it).

There are many good epoxies on the market, with Aeropoxy, US Composites and West Systems being very popular. Just look for a brand that is fairly low viscosity so it flows well and will self level when applied to the surface.

Once mixed, the liquid epoxy can be simply painted onto the surface of the fin. Try to keep it to a minimum, or your skill will be thick and heavy. In Figure 7, you'll see a fin that has epoxy partially painted on the surface.

What if You're Applying Skins like Fiberglass or Carbon Fiber?

If you were applying a skin in addition to the epoxy, you probably would skip the step of sealing the balsa fin and simply wet the surface of the fin with epoxy, and then apply the skin on top, and rewet the skin with epoxy.

I've never done a thick skin on a fin, but I suspect that if you did, you might have to do just one side of the fin at a time, and also add a "peel ply" over the top before you put it into the vacuum bag.

The peel ply (also called a release fabric) is a synthetic cloth that you drape over the epoxied surface after you've wet it out.

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What does peel ply do?

Say your surface of the fin is not perfectly smooth, and has some very broad valleys in it. When you lay the fiberglass cloth on the part and add epoxy, and then put it inside the vacuum bag, the upper surface will want to self level out. You'll end up having a broad puddle of epoxy on the surface that fills the shallow valley. That means you will have excess epoxy on the part, and that adds unnecessary weight.

To get rid of this excess epoxy, you can put a slippery cloth on top of the skin. This is the peel ply. This cloth will also follow the curvature of the valley under the skin, and the excess epoxy will pool on top of it. Essentially, nothing changed in this situation, and we still have a pool of epoxy on the surface.

But once the epoxy is cured, we can simply pull off the peel ply fabric, and the pooled-up epoxy will come off with it. So we can get rid of a lot of weight by using peel ply.

And this is why people think that vacuum bagging will squeeze out excess epoxy. It isn't that we're squeezing it out, we're just removing the large puddles on the surface of the part. It is still totally possible that the cloth is still oversaturated with epoxy that it doesn't need for strength.

A lot of people say that peel ply will leave a smooth surface. The word "smooth" is relative. What they mean is that it will be free of big clumps and hairs of fibers protruding from the surface. Those clumps and hairs are pressed down by the peel ply. But the surface will still have a texture to it. The texture will be the roughness of the cloth used for the peel ply. For example, think of rubbing your fingers across the surface of a cloth umbrella. It is "smooth," but not "glass-smooth."

The nice thing is that the surface can be lightly sanded and then polished, and it is possible to get it glass-smooth. But it does require extra work.

Using peel ply may require only doing one side of the fin at a time. The reason for doing only one side at a time is because the peel ply would be difficult to remove from the edges of the fin if the two pieces of epoxy-filled peel ply touched each other. That's just my guess though, since I haven't used peel ply on fins.

If you're using peel ply, you will also need breather/bleeder cloth over the entire surface. This will both soak up the excess epoxy on the surface of the peel ply, and also allow air bubbles to escape. Both the peel ply and the breather cloth are thrown away after they touch the resin, as they will be clogged up after the epoxy is cured.

In my particular application, where I'm trying to get a smooth skin on the surface of the fin, I did not use a peel ply or bleeder cloth directly on the part. I want the fin to touch the side of the bag so the surface is completely smooth once the epoxy is hardened.

At this point, the whole thing is inserted into the vacuum bag.

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FIGURE 8: THE EPOXY COATED FINS ARE PUT INSIDE THE VACUUM BAG. THE BREATHER CLOTH SHOULD BE AS CLOSE TO THE FINS AS POSSIBLE. THERE SHOULD ALSO BE A PIECE OF BREATHER CLOTH WHERE THE EZ-CONNECTOR IS ATTACHED TO THE BAG. THE BREATHER CLOTH GIVES THE AIR A PATH TO FLOW OUT OF THE BAG.

The EZ-Vac connector is attached to the bag by cutting a small hole into one side of the bag, and putting the fitting through from the inside of the bag, and then locking it down with the nut on the outside.

The EZ-Vac connector just needs to be off to the side of the fin slipped into the bag. Under the connector, and all around the perimeter of the fin(s), you'll need to lay down strips of breather cloth. I found that using a bigger bag than necessary helps to move the breather cloth around, particularly along the edges of the bag.

Just make sure the breather cloth doesn't touch the edges of the fins, or you'll ruin the surface finish of fins. But you do want it as close to the edges as possible to help the air bubbles on the surface of the fin to escape out and the plastic to be sucked down as tight as possible.

When everything is positioned in the plastic bag, you'll attach the Quick Lock seal over the open end of the bag. The vacuum hose is connected and the vacuum pump is turned on.

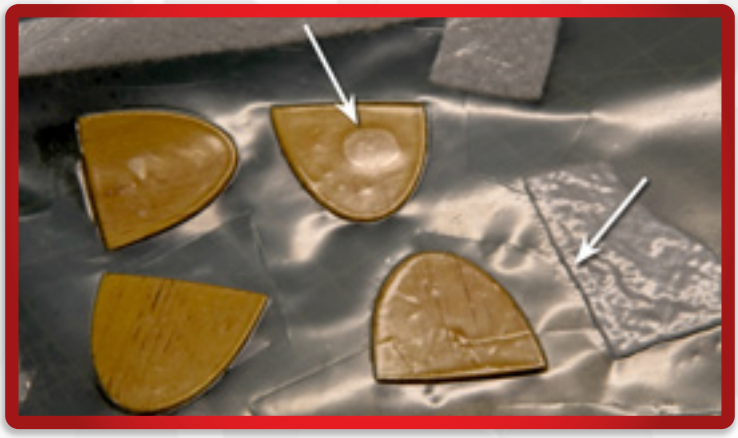

FIGURE 9: AN AIR BUBBLE TRAPPED ON BETWEEN THE PART AND THE PLASTIC BAG. NOTE THE SHARP EDGE AROUND THE EDGES OF THE PARTS AND THE BREATHER CLOTH, INDICATING A STRONG VACUUM BEING PULLED ON THE BAG.

As the air is being sucked out of the bag, you'll actually have to use the pads of your fingers to slide any bubbles off the surface of the fins. This can be done while the epoxy is still wet, because it acts as a bit of lubricant on the surface.

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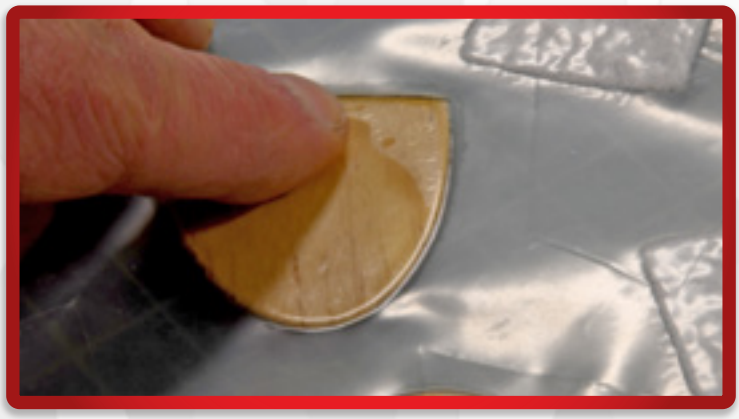

FIGURE 10: USE YOUR FINGERS TO WORK THE AIR BUBBLES TOWARD THE EDGE OF THE PART, SO THEY ARE ELIMINATED

You do have to flip the bag over and also work out the air bubbles on the opposite side of the fins.

FIGURE 11: THE FIN INSIDE THE VACUUM BAG, WITH ALL THE AIR BUBBLES PUSHED OFF THE SURFACE

Before walking away, make sure the fins are flat. Once the epoxy cures, you can't flatten them out again. I typically like to put some flat heavy weights on them while the epoxy is curing.

As I mentioned, I leave the pump running until the epoxy is cured, because I've never been able to get everything sealed perfectly airtight.

When the epoxy is cured, you can turn off the pump and remove the fins from inside the bag. The epoxy doesn't stick to the plastic bag, but the fins typically are clinging to the plastic with surface tension. But, they will easily pop off if you shake or pry up an edge.

FIGURE 12: BY ANGLING THE LIGHT REFLECTED OFF THEM, YOU'LL SEE THE FINISHED FINS ARE MUCH SMOOTHER. ANY BLOTCHY LOOKING AREAS DO NOT HAVE ENOUGH EPOXY ON THEM. NOTICE ALSO THAT THERE IS A LITTLE BIT OF FLASH ON THE EDGES WHERE EPOXY WAS SQUEEZED OFF THE FIN.

At this point, it is just a matter of cleaning up the edges of the fins with a little bit of light sanding.

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Conclusion

The process of vacuum bagging may seem a little daunting if you've never done it before. But I found it fairly easy to accomplish once you have all the correct equipment. Once you do one piece, you'll find it isn't too hard.

While we don't often need vacuum bagging in model rocketry, there are a few instances where it does come in handy. Hopefully this will give you some ideas for future projects of your own.

FIGURE 13: A COMPARISON IN WEIGHT OF A NORMAL FIN VERSUS ONE THAT WAS SKINNED WITH EPOXY.

In a future article, I'll show you how to use vacuum bagging to make chrome-plated wood fins. So you get the weight savings of a balsa fin, with the bright chrome look that makes the rocket sparkle in the sunlight. Observers will think they are really metal fins.

Supplies needed:

- **Vacuum pump:**
  You can also use an airbrush compressor. Get at Harbor Freight or Amazon.
- **Breather Cloth:**
  It is reusable, so you don't need much. Get the minimum amount needed.
- **Quick Lock Seals:**
  https://store.acpcomposites.com/quick-lock-seals
- **EZ-Vac Connector:**
  https://store.acpcomposites.com/ez-vac-bag-connector
- **Tubing Clamp:**
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Additional Resources:

- **Press for fins:** https://www.apogeerockets.com/education/downloads/Newsletter509.pdf
- **Food Sealer vacuum bagging:** https://www.apogeerockets.com/education/downloads/Newsletter396.pdf
- **Surface mount fiberglass fins:** https://www.apogeerockets.com/education/downloads/Newsletter332.pdf
- **Using Fiberglass in Rocketry:** https://www.apogeerockets.com/education/downloads/Newsletter311.pdf
- Check YouTube for videos on Vacuum Bagging. There are a lot of good videos there, and it is where I learned most of the techniques described in this article.

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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