How to Make "Composite Paper"

Introduction

"Composite paper" is a technique for making very light sheet material suitable for FAI competition models and other lightweight applications. Using this approach, it is possible to create 40 mm S3A/S6A body tubes with mass less than five grams. This technique was first popularized in the US by Kevin Kuczek.

There are four potential advantages of composite paper. First, it may be possible to build a model that is lighter than can be achieved using the traditional mandrel approach. Second, you eliminate the difficult operation of removing a fragile body tube from the mandrel. Third, you can easily use different materials/layups for different portions of the model. For example, you can use a minimum weight sheet for the cylinder and a stronger/stiffer material for the boattail. Lastly, you can roll the composite paper into any size tube, such as making lightweight body tubes for scale models.

The techniques and tools required to make composite paper are fairly simple. If you already have some experience making traditional FAI models using light fiberglass, the techniques are similar.

Layup Tool

The first step is to obtain a layup tool that is smooth, flat, and the right size. An easy source for a layup tool is a glass shelf from a home supply store such as Home Depot. At time this article was written, a good glass shelf was the Home Depot Mural Glacier 8 in. Clear Glass Shelf[1]. This shelf is 8" x 24", which is sufficiently large for FAI bodies. The shelf is ~3/8" thick and quite strong. [Note: it is not advised to use thin window glass as this might shatter during handling or vacuum bag activities.]

[1] http://www.homedepot.com/p/Mural-Glacier-8-in-Clear-Glass-Shelf-Price-Varies-by-Length-MHDGL9020CL/100632155#.UYbNS8ribSg

Materials

There are a variety of composite materials that can be used for making composite paper. Typical materials include the following:

- 0.58 oz/yd^2 fiberglass fabric
- 0.73 oz/yd^2 fiberglass fabric
- 1.4 oz/yd^2 fiberglass fabric
- 0.2 oz/yd^2 carbon veil
- 0.3 oz/yd^2 carbon veil
- 0.5 oz/yd^2 carbon veil
- Esaki Japanese tissue
- ¼ or ½ mil Mylar

Fiberglass fabric has been used most often. Some recent work has been done using carbon veil. The carbon fibers have much higher strength and stiffness than fiberglass. However, the carbon strands are arranged in a dispersed random pattern which may produce weak zones. Esaki tissue and thin Mylar have been used as a support/sealing layer. The best material (or combination of materials) may depend on model geometry and motor type. For example, a model constructed for US competition using 13mm or 18mm motors would likely need stronger construction than a model constructed for FAI competition using 10mm motors with lower thrust and smaller ejection charges.

The lightest layup would be a single ply of material. However, the resulting sheet might be too fragile to survive flight. Adding a layer of Esaki tissue seems to improve strength without adding too much additional weight. Some people prefer to use thin aluminized Mylar instead of tissue.

Epoxy Resin

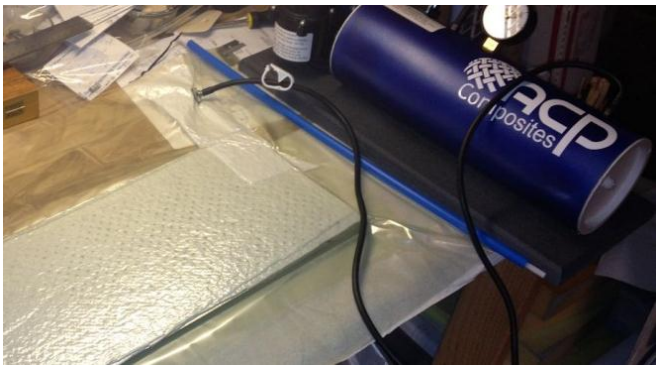
Composite paper can be made using two-part epoxy resin systems that cure at room temperature. Low viscosity resins (such as West System[2] 105 resin with 206 hardener, or EZ-Lam 60[3]) are suitable. Medium viscosity resins (such as Aeropoxy[4] PR2032 resin with PH3660 hardener) can also be used. However, it may be more difficult to apply a medium viscosity resin to thin delicate laminates.

Note that epoxy's nominal setting and cure times need some interpretation. "60 minute hardeners" mean that the resin will start to gel at ~60 minutes at a temperature of ~75°F. However, the resin won't become reasonably hard for several

[2] http://www.cstsales.com/west_system_epoxy.html
[3] http://www.acpsales.com/EZ-Lam-Epoxy.html
[4] http://www.aircraftspruce.com/menus/cm/epoxy_aeropoxy.html

hours. The resin takes ~24 hours @ ~75°F to become sufficiently cured such that the composite paper can be handled. However, achieving full cure may take an additional 24 to 48 hours. If you're working in a cold basement or garage, the set and cure times will be even longer. Working at higher temperatures and/or performing the cure in a "hot box" will reduce set and cure times.

Vacuum Bagging



Using a vacuum bag will help reduce the weight by eliminating excess resin from the laminate. Some special equipment is needed, but the process is straightforward.

A very convenient system is produced by ACP Composites[5]. A starter kit includes the Auto-Vac vacuum pump system, bag material, sealing clips, and breather cloth. The vacuum pump includes a user-adjustable vacuum limit switch such that the vacuum pump does not need to run continuously. The ACP Auto-Vac system is very convenient but not cheap. A variety of lower price options can be found on the internet.

This document assumes that vacuum bagging will be done using the ACP bag tube and clip supplies. However, a layup (w/o tissue) can be performed at ambient pressure, although the resulting laminate might be somewhat heavier due to excess resin. Tissue will tend to absorb resin and may wrinkle if the laminate isn't under pressure.

Step 1 – Prepare Vacuum Bag

Cut a length of vacuum bag tube to the length of your layup tool plus ~4" margins on each end. If using a 24" long glass shelf as the tool, the bag should be ~32" long.

Cut a small (~1/4" square) hole in **only the top surface** of the bag at ~4" from the end and ~3" from the edge of the bag. Place the hose fitting inside the bag and push the connector tube through the hole in the bag. Tighten the nut and washer on the outside of the bag.

The bag is reusable. However, it tends to develop micro holes during each use. If the bag starts to leak too much, you'll need to discard the old bag and make a new one. Bags should last 10-20 cure cycles.

[5] http://www.acpsales.com/Vacuum-Bagging.html

Step 2 –Materials Kitting

The first step is to prepare a kit of all of the materials that will be used in the laminate and (optionally) vacuum bag. Cut out the following materials:

- Non-perforated release ply (two sheets)
- Laminate materials (for example, one ply of fiberglass, one sheet of Esaki tissue)
- Perforated release ply
- Breather cloth

It is recommended to make a template (from card stock or cardboard) to help cut out the material to the correct size in a repeatable manner. You should also use a composite cutter and cutting mat to easily cut fiberglass and carbon veil. Use scissors to cut breather cloth. Scissors or razor blades are best for cutting release ply.

Step 3 –Layup Tool Preparation

Epoxy is a very strong bonding material. You you must prepare the layup tool carefully so that the epoxy does not bond to the glass.

Apply a layer of mold release wax (such as Meguiar's mold release wax[6]). Be sure to cover the entire top surface of the glass. Allow the wax to dry, then buff to remove excess wax and achieve a good shine. If desired, repeat the wax application and buffing.

The layer of wax might be sufficient release treatment. However, to be prudent, apply a layer of release agent. Spray-on release (such as LPS MRX silicone mold release[7]) provides a smooth uniform finish. Liquid release (such as FibRelease[8])might also be used. If using liquid release, allow the release material to dry before proceeding with the layup.

[6] http://www.fibreglast.com/product/Meguiars_Mold_Polish_Conditioner_and_Release_Wax_118/Mold_Releases
[7] http://www.aircraftspruce.com/pages/cm/moldrelease/lpsSiliconeMold.php
[8] http://www.fibreglast.com/product/FibRelease_01153_A/Mold_Releases

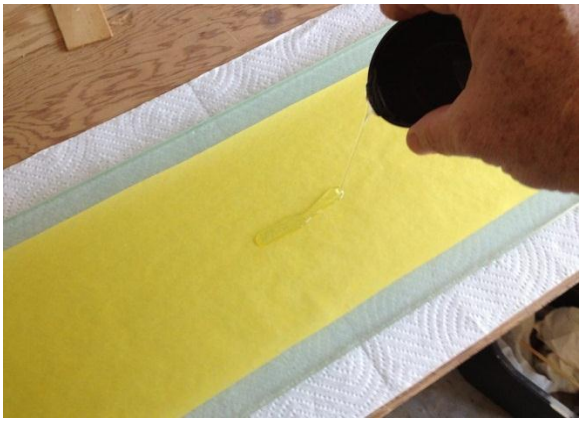
Step 4 –Mix Epoxy Resin and Hardener

Mix the epoxy resin and hardener using the ratios specified by the manufacturer. Most manufacturers will specify a mixture ratio based on mass. Some manufacturers specify a mixture ratio based on volume.

The total amount of resin to mix depends on the size of the laminate and the number of plies. If you're using a 8" x 24" glass sheet described previously, a total of ten grams might be about right.

Be sure to accurately measure the resin and hardener amounts. Using a scale accurate to 0.1 grams is recommended. After pouring the resin and hardener, be sure to stir very thoroughly.

Step 5 – Layup



Place the first (outer) ply of material on the layup tool. The first ply will typically be a sheet of Esaki tissue or 0.5 oz fiberglass in order to achieve the smoothest outer surface.

Next, apply some of the mixed epoxy onto the laminate. You can paint it on using a throw-away brush. However, a faster method is to drizzle the epoxy directly on the ply. Use a spreader tool to gently spread the epoxy and wet-out the laminate. You can buy spreaders from composites vendors, or you can make one from a piece of plywood with a smooth, straight edge. When using the spreader, start from the center and wipe towards the sides and ends. This helps prevent wrinkling the ply.

If there are additional layers of the laminate, carefully place the next ply onto the wetted-out first ply. Apply more epoxy, and spread the epoxy to wet out the additional ply. Repeat this process until all of the plies are done.

The final step is to use the spreader tool as a squeegee to remove any excess epoxy from the laminate. Remember that the strength of the laminate comes from the plies, so excess epoxy only adds unnecessary weight. You'll quickly get a feel for how much pressure to apply to remove excess resin.

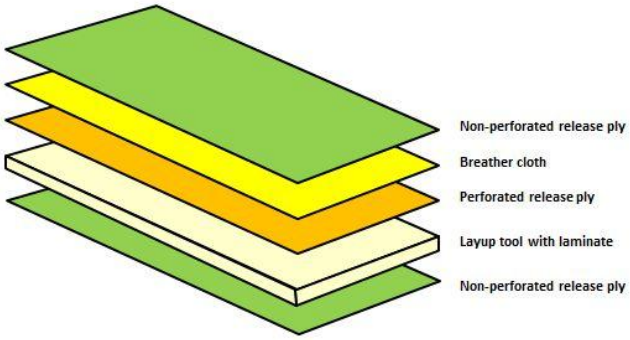
If you're not using a vacuum bag, you're done with the layup.

Step 5 – Vacuum Bag

Using a vacuum bag can remove more excess resin than by manual squeegee. It will also prevent laminates with tissue or carbon veil from wrinkling due to epoxy moisture absorption.

The next step is to make a "sandwich" with the following (from top to bottom):

- Non-perforated release ply
- Breather cloth
- Perforated release ply
- Layup tool with laminate
- Non-perforated release ply



The perforated release ply allows any excess resin to bleed out of the laminate and into the breather cloth. The top and bottom layers of non-perforated release ply prevent the assembly from bonding to the vacuum bag. You can use some masking tape to keep the "sandwich" assembled.

Slide the "sandwich" inside the vacuum bag. Use a small length of breather cloth to bridge from the breather cloth in the "sandwich" to the fitting in the vacuum bag. Apply the clips to the ends of the bag. Attach the vacuum line from the vacuum pump to the fitting. Turn on the vacuum pump and monitor the bag as the air is removed. You might have to smooth it out a bit to make sure that wrinkles don't form in the bag.

Step 6 - Demolding

Wait at least 24 hours to allow the resin to reach its initial cure condition.

If you've used a vacuum bag, perform the following steps:

- Turn off the vacuum pump and disconnect the vacuum line from the bag.
- Remove the clips from the vacuum bag.
- Remove the layup "sandwich" from the vacuum bag. Set the bag aside for reuse.
- Remove the top and bottom layers of non-perforated release ply. Set these aside for reuse.
- The breather cloth will have small amounts of epoxy where excess epoxy was squeezed through the holes in the perforated release ply. Carefully remove the breather cloth by taking one corner and pulling horizontally (parallel to the layup tool). Don't pull too hard as you might damage the composite laminate itself. Due to the absorbed epoxy, the breather cloth is not reusable and should be discarded.
- After removing the breather cloth, remove the perforated release ply. If the release ply removes cleanly (and it should), you could reuse this.

- Use some 220 sandpaper and sand down the small epoxy nubs formed by the perforated release ply. Be careful not to excessively sand the laminate itself.

The composite laminate is very thin, and care must be used to remove it from the tool. First, slip the edge of a single edge razor blade between the laminate and the tool. Run the razor blade completely around the edge of the laminate to make sure the edges of the laminate are free from the tool. Next, start sliding something very thin between the laminate and the tool. A piece of 0.005" fiberglass sheet works well, but other thin items (like card stock paper, 1/64" plywood, or a steel ruler) should work. Continue sliding the demolding device until the laminate has been separated from the layup tool. Work carefully so that you don't wrinkle the laminate.

At this point, the laminate can be set aside for another day (or two) to reach a fully cured state. If desired, the paper can be rolled and stored in a tube during the additional cure so that the fully cured sheet will be pre-shaped. After the additional cure time is completed, the laminate is ready for use.

Examples

Typical mass properties for selected composite paper layups are provided in the table below. Your results may vary depending on your materials, resins, vacuum bag methods, and other techniques. Note that some of the lighter laminates may not be sufficiently strong for use with FAI-style models using U.S. 13 mm motors.

Description	# Ply	Material	# Ply	Material	Resin	Mfg Method	Areal Mass (gr/in^2)
1 ply 0.75 oz FG w/o tissue	1	0.75 oz FG	-	-	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0366
1 ply 0.2 oz veil w/tissue	1	0.2 oz carbon veil	1	Esaki tissue	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0385
1 ply 0.5 oz FG w/tissue	1	0.5 oz FG	1	Esaki tissue	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0405
1 ply 0.5 oz FG, 1 ply 0.2 oz veil	1	0.5 oz FG	1	0.2 oz carbon veil	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0463
1 ply 0.75 oz FG w/tissue	1	0.75 oz FG	1	Esaki tissue	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0468
1 ply 1.4 oz FG w/o tissue	1	1.4 oz FG	-	-	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0527
1 ply 0.3 oz veil w/tissue	1	0.3 oz carbon veil	1	Esaki tissue	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0547
1 ply 1.4 oz FG w/tissue	1	1.4 oz FG	1	Esaki tissue	EZ Lam (60 min)	Vac Bag w/ perf release ply	0.0664

Summary

Composite paper is handy method for making very light sheets for competition models. A wide variety of materials can be used to achieve the desired weight and strength properties.

Bill of Materials

- Layup tool

- Composite materials (fiberglass, tissue, etc.)
- Composite cutting tool
- Epoxy resin and hardener
- Scale
- Epoxy spreader
- Vacuum bag supplies
    - Vacuum pump and hose
    - Vacuum bag and fitting
    - Non-perforated release ply
    - Breather cloth
    - Perforated release ply