More Composite Basics

Part 2 concludes lessons learned at an Oshkosh forum last summer.

BY ANN ENMAN

Unidirectional, in which all strands are going in the same direction, or bidirectional weaves are available in explained Ralph Bradshaw of Alpha Plastics during his composites forum at the EAA convention last summer.

Referring to basic plain weave, he said, "Rutan 7075 cloth is a material that doesn't interweave as much and, with less friction in the cloth, it is more flexible and will curve around corners maintaining its strength. Glasair and Lancair use satin weave—a fine, satiny, pretty cloth with a tight weave with which you can get a dense laminate, although it is hard to wet out sometimes."

At his forum, Bradshaw recommended a group of good source books for those interested in further study of composite basics. He named Martin Hollmann's *Composite Aircraft Design*, Jack Lambie's *Composite Construction* and Andy Marshall, widely known and respected for his knowledge of materials, whose book, *Composite Materials*, was in revision.

Depending upon goals, a builder could possibly use one or all fiberglass cloths, Bradshaw indicated. Knitted fabric, that is, unidirectional strands that are laid at different angles and knitted together, is popularized as biaxial fabric. With a plus or minus 40° bias, it curves around corners well because the fibers are not kinked. As kinking reduces strength, a net of 10 to 15% more strength is obtained compared to woven fabric.

Prepregs are reinforcements that have been preimpregnated with a resin system. Bradshaw cautioned that prepregs aren't as easy to use as would be hoped. Prior to reaching the customer, it is necessary to initiate or mix the hardener and resin together, impregnate it into the cloth and quick-freeze it to slow the setup time. The customer receives it, unrolls it, molds it and heats it to 250-350° to get the prepreg to cure as a final product.

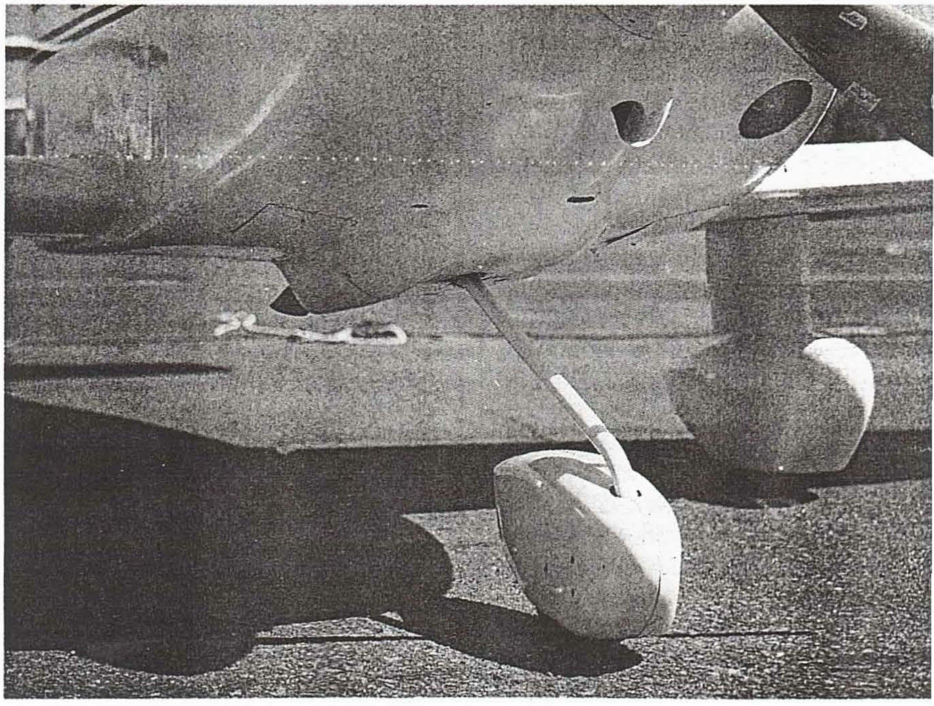
"Prepreg setups are expensive," said Bradshaw. "One industrial manufacturer figured a cost of $150,000 to set up for a minimum prepreg operation and decided that, unless it was a big job, it was going to be hard to get started. Perhaps someone could figure how to do it for $500, but it takes freezers, ovens and high-temperature tooling to do it right. The resin and dry fabric are expensive; yet good, consistent parts can be produced rapidly."

Vacuum bagging is one method of processing that has existed for a long time, has been used by many but is still somewhat mysterious. "If you are dealing with a vacuum bag," Bradshaw said, "you draw a vacuum on a laminate, remove the air bubbles and simultaneously remove the excess resin, improving the laminate quality. It will accomplish a better laminate out of a good laminate. But I found out the hard way, it will not take a bad laminate and make a good one. It will make it into a more labor-intensive piece of junk.

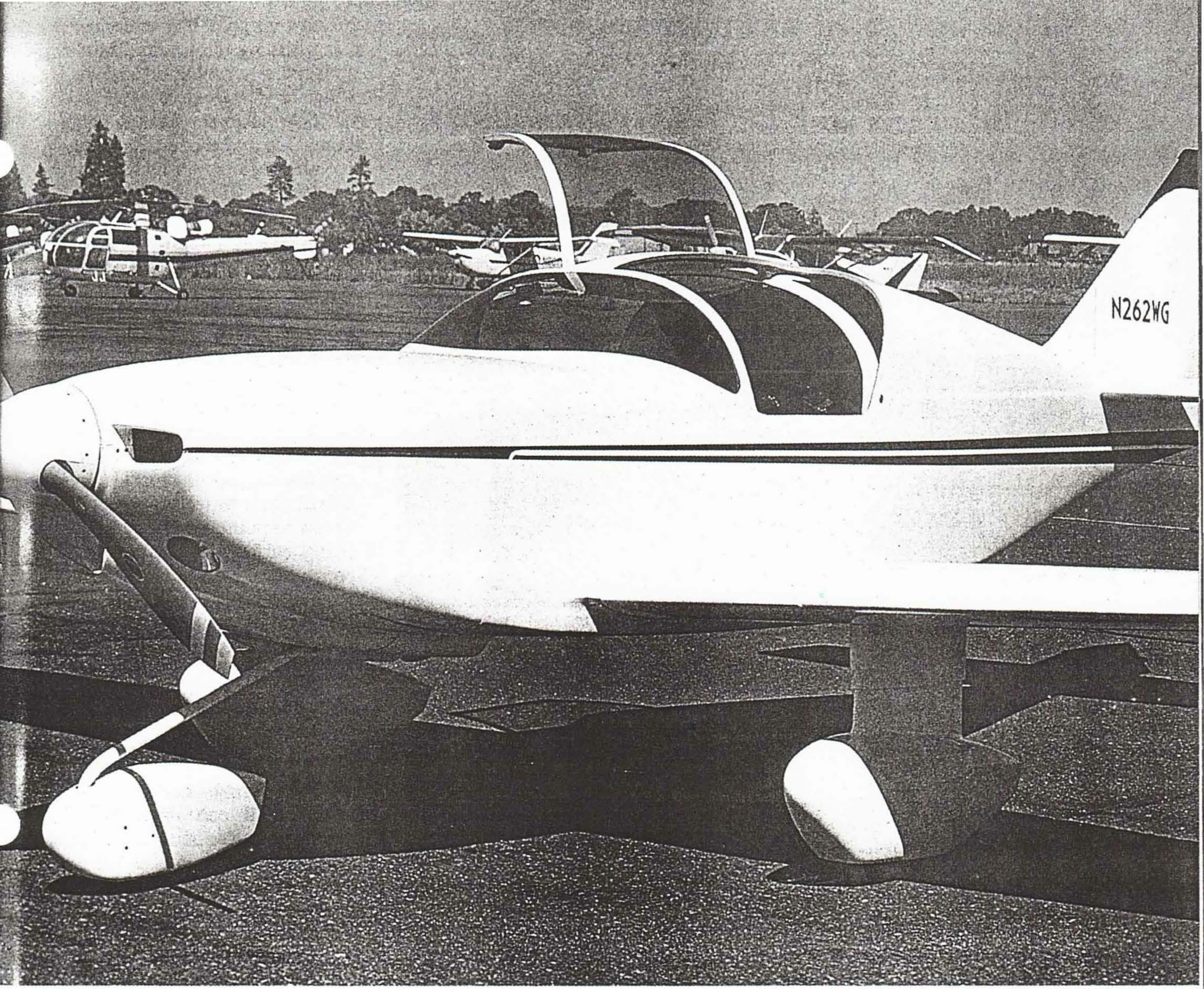
"Use good techniques and ensure that the weave is straight. Vacuum bagging will remove excess resin, but it will not cover up mistakes; it will magnify them," he said.

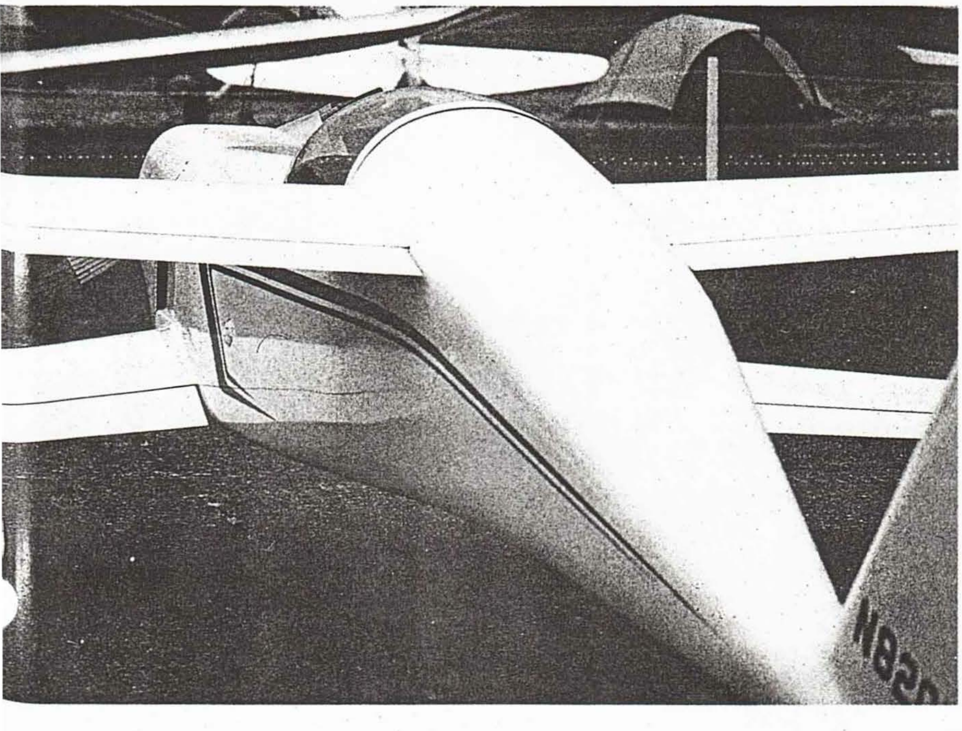
What can be accomplished with vacuum bagging? Let's choose to make the simplest shape, a flat panel, bagging into a mold. Do the layup—the laminate, (perhaps E glass cloth and epoxy resin), spread out and wetted on the table. Cover it with a layer of peel ply (a release fabric of woven polyester that will not adhere after it is all cured). The porous release layer will be right on top of the wet laminate. Then a

Wayne Avery's Glasair illustrates a polyester-based composite aircraft whose parts are factory-made in female molds by hand layup.



Composite structures lend themselves to complex compound shapes and smooth finishes.





layer of absorptive material—spun polyester, burlap bags or paper towels —that also communicates the vacuum over the whole surface. On top put a non-porous, non-permeable bagging material such as polyethylene film or Visqueen.

"Think of it as a plastic trash bag over the whole thing," Bradshaw said. "Pleat the bag, seal it with tape around the edges and pull a vacuum. For a vacuum, use a refrigerator compressor, a vacuum cleaner or an air conditioning compressor. It is not necessary to buy a $1000 vacuum pump."

The steps, again:

1. Mold.
2. Glass and epoxy.
3. Peel ply.

This Quickie was built with epoxy resins using the Rutan moldless technique.

4. Bleeder—shredded paper, spun polyester or paper towels.

5. Sealed bagging film all the way around.

6. Build a pleat into it to take up the slack and communicate the vacuum. If you don't have the vacuum all over the part, you are not going to get a consistent part.

7. Seal it with an attachment for the hose."

How much vacuum is necessary? The amount of vacuum depends on the geometry of the part and the number of layers. More pressure is necessary for a multi-layer part than a part that consists of two layers. A minimum of 5 inches of vacuum is required.

"You could almost do that with your mouth," Bradshaw said, "but you can't do it for 24 hours. Half of a vacuum—about 7 pounds per square inch—translates roughly to 1000 pounds per square foot. The pressure squeezes onto the wet resin, squashes the reinforcement and forces the resin out through the porous layer where it is absorbed by the bleeder material. When everything is set up, shut down and pull off the peel ply, which carries off extra resin that has already been absorbed above it.

"Vacuum bagging gives you a minimum-weight, minimum-resin-content part with no bubbles. Play with it and you will realize that it is a good way to get a high-quality part."

What about vacuum bagging a wing? Bradshaw explained putting a wet layup on top of wing, bagging that part of it and putting a bag underneath the wing, sealing the top and bottom together. It amounts to sacking the entire wing.

"One customer makes wings for Long-EZs and Cozys," he said. "He vacuum-bags them and claims that 8 pounds per wing can be saved. Let's take an example: if the laminate had 100 pounds of glass and a hand layup of 50/50 ratio, it would require 100 pounds of resin. If vacuum bagging could reduce the equation to 60% reinforcement/40% resin, the reinforcement remains at 100 pounds, resin drops to 67 pounds and effectively saves 32 pounds.

"That may not actually be realized, but it suggests what can be done with vacuum bagging. In most kit airplanes, it is difficult to realize everywhere—it would be in the wings, the canard, the flying surfaces, bulkheads and flat panels. It is hard to bag a fuselage because it is difficult to hold the shape. Is vacuum bagging worth doing? That is up to the builder."

For advanced-temperature curing—if you are in production, it may make sense. The problem is that everything must be kept jigged and molded because the epoxy is going to tend to relax and permanent sags can be introduced. You can improve physical properties of resins by advanced-temperature curing.

"One problem with advance-temperature curing is that you have to have the molds for it," Bradshaw said. "Regular polyester resin is really not usable as a high-temperature molding resin but new resins have been introduced that can fabricate a high-temperature master. Such a mold can be heat-cured without changing dimensions.

A builder could build a prototype, make a mold of foam and wallpaper paste and use it for prepregs and high-temperature parts—a new concept and not very expensive.

In response to questions about combinations, Bradshaw said, "Use a hybrid (Kevlar and glass, for example) to get combination of strengths. A graphite/Kevlar hybrid gives you some of the toughness of Kevlar and stiffness of graphite. It wouldn't be as stiff as all-graphite nor as tough as all-Kevlar. If you've thought about using Kevlar, instead of putting it all over the airplane, put a square right under the hockey puck of the nose. When you land gear-up, you can put the gear back down and fly off before anybody knows you're there. Otherwise you've a lot of repair."

What about Allied Technologies Spectra Fabric? "Newly introduced, there are only a couple of weavers in the country that make it." Bradshaw said. "It's white fabric that kind of competes with Kevlar. I thought it might wet out clear, but it remains an opaque white although it has higher compression strength and higher heat resistance. At this moment, no one is designing around it and it is primarily in the marine market. Allied is pushing it so I'm sure we'll see more of it."

Polyester versus epoxy? "The bond of polyester to anything is basically mechanical, Bradshaw said. "It holds onto the roughness of the surface—the peaks and valleys. Epoxy has a chemical bond. The hardener and resin together actually form chemical linkages with the surface and with each other. In the wooden area—wooden boats, for example—they use a lot of epoxy to encapsulate the wood. Epoxy forms a stronger bond to wood than polyester."

Bradshaw concluded, "There's a high-temp Divinycell—Lancair makes use of some of that. Generally, basic types of Divinycell are good to about 170 to 180°F. Polystyrene foam is probably good to 150-160°F. Those are the kinds of temperature limits with which a builder is working. □

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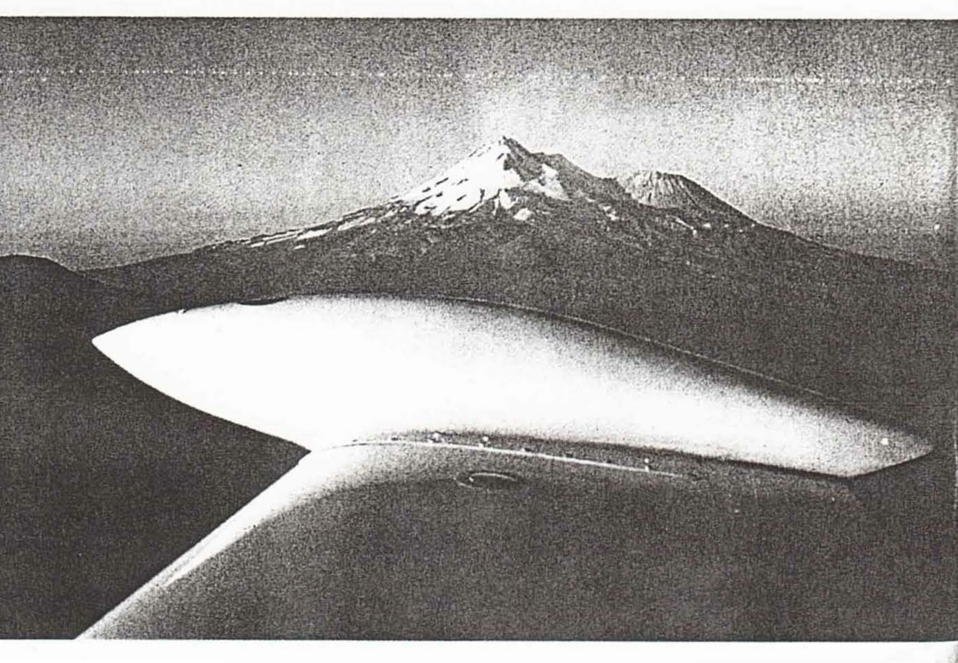

Celerity's composite wing and tip tank illustrate a level of smoothness and finish difficult to achieve with homebuilt lightweight metal structures.