BRUCE PFUND

The Burnout Test

A standard procedure for getting basic-but-vital data about your FRP laminates generally requires sending out hull or deck samples to a composites lab. A *modified* testing procedure, though, offers more useful results.

by Bruce Pfund

Above—*Burned in a boatyard accident, the hull illustrates the guiding principle of a laboratory burnout test: resin burns away and glass fabric remains, enabling technicians to calculate the fiber-to-resin ratio and examine the laminate schedule, all in a small test coupon.*

Fiber-to-resin ratio is a critical property of marine composites. Quality assurance and failure analysis require reliable information on whether a laminate is resin rich, resin starved, or just right. On the manufacturing side, variations in resin content can complicate purchasing and material handling at the boat plant, as well as accurate weight predictions.

In-house laminate testing can go only so far. The best way to determine fiber-to-resin ratios and confirm laminate schedule and fiber orientation is with a burnout test based on American Society for Testing and Materials, or ASTM, guidelines. Most builders have to ship samples off to a test lab that has specialized equipment and skills. Independent laboratory testing of composites and coatings isn't cheap. Even when the method seems as simple as the standard burnout test, in order to get the most bang for your buck you've got to be aware of just how the testing works, and what results you can reasonably expect.

A yet-to-be-tested 1-sq-in (6.4cm^2) coupon, at left above the ruler, and, at right, a cross-section view of the laminate, contrast with the burnout-tested coupon in the foreground. Note how the tested laminate has been disassembled, clearly revealing the interface between roving (left) and chopped strand mat (right).

Basic Burnout

At the lab, a laminate sample is prepped, weighed, and placed in a ceramic crucible in an electric muffle furnace at about 1,050°F (565.6°C). After the resin is burned out, the sample is cooled and weighed again. By comparing sample weights before and after the burn, the lab can calculate the fiber-to-resin ratio. By separating and weighing the layers of fiberglass, the weights and orientations of various plies can be determined.

This basic test may sound straightforward enough, but it's beyond the capability of most boatshops. Typically, builders cut a holesaw coupon out of a solid fiberglass laminate, send it off to a test lab, and request a burnout test for resin content and ply weights and orientations. If, however, you don't give the lab more specific instructions, then the resin-content figure you get back may not reflect actual laminate properties.

According to Art Wolfe, lab manager at Structural Composites in West Melbourne, Florida, "Most of the standardized composite tests are designed to test samples *made in a lab*, not holesaw coupons *cut in the field*."

How do field-grade samples differ from lab-made samples? Well, *boats* are gelcoated, while most lab samples are not. If gelcoat and bilge coats from the finished boat are left on during testing, the sample will appear more resin rich than the actual structural laminate really is.

Instruct the lab to sand off the gelcoat. Even then, if the gelcoat's back surface is lumpy and orange-peel textured, sanding away *all* the gelcoat might remove some skincoat, and reduce the accuracy of the areal weight prediction.

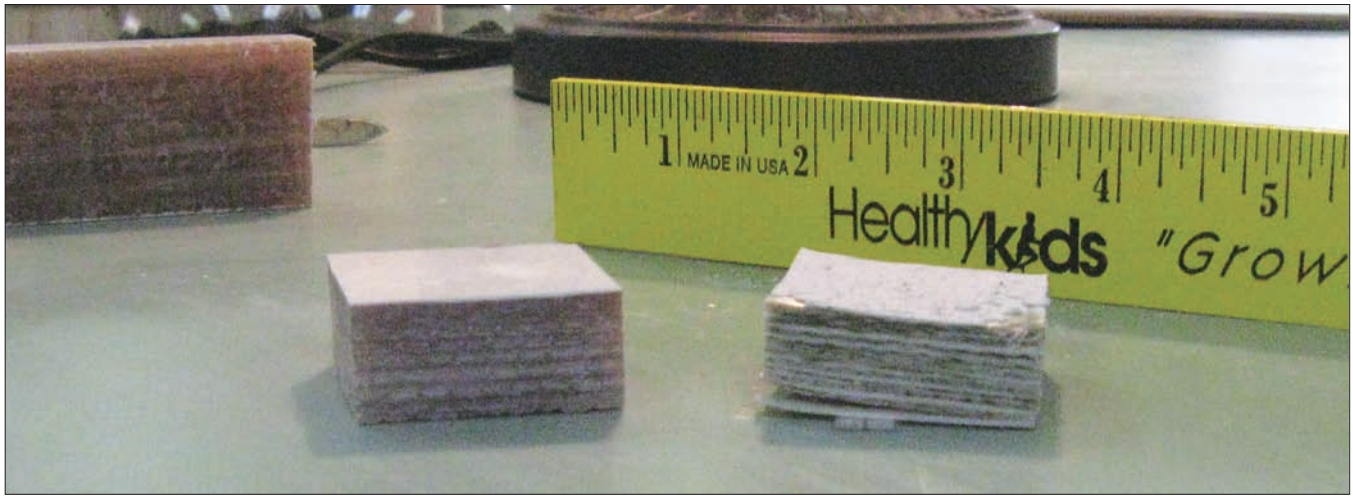
Wolfe said that he usually removes about 90% of the gelcoat—just until the skincoat color appears. "Remember, there are no fibers in gelcoat, but it *is* heavily loaded with pigments and fillers, so gelcoat won't really skew the resin-content results that much," he said.

I prefer writing instructions *on* the samples about removing any surface coatings, followed by a short chat with the technician *who will actually be conducting the work*, not with, say, the lab's supervisor.

You should also specify whether you want to include the resin-rich skincoat in the test. Leave it in place,

During a burnout test, coupons in crucibles are subjected to muffle-furnace temperatures of about 1,050°F (565.6°C). To allow fiber-orientation analysis, the samples' orientation is carefully maintained by indexing the coupons to a reference mark on each crucible's rim.

ART WOLFE (BOTH)



ART WOLFE

A burnout-tested sample (right) is visibly thinner than the original laminate (left). The calculated resin content is the difference between the original laminate's weight and the weight of the same sample after its resin has burned away.

and the whole sample will read as more resin rich than it really is. In fact, the skincoat should be perhaps 60% resin or more by weight, while the long-fiber layers underneath should have 10% lower resin content—perhaps even less resin if the part was infused. By cleaving the skincoat off from the balance of the long-fiber plies, and testing that layer separately, you may be able to better assess whether expected lower resin content is consistent in the laminates underneath. If you test them together, you'll get an unrepresentative average reading that's not accurate for either.

A good lab should warn you that it's not always possible to determine whether a mat layer was applied individually, was sprayed chop or roll goods, or if the chop was part of a rovings/biaxial and mat combination. The z-axis fibers in stitch-attached mat *might* remain after burnout; or

Accon Marine

- Available in marine grade 316 SS or aluminum.
- Easily removes when not needed, simply snap back into place when needed again.
- Surface mount, no cut-outs necessary.
- Installs with two # 10 screws.

- Available in single or double styles
- Vertical mounts available

727-572-9202 • 727-572-7621
13665 Automobile Blvd. Clearwater, FL 33762
www.acconmarine.com

LEARN BOAT DESIGN AT WESTLAWN

"85 ft Motoryacht" RICHARD MCBRIDE • WESTLAWN ALUMNUS

FOR OVER 80 YEARS, Westlawn has educated many of the world's finest boat and yacht designers. You'll learn at home, at your own pace, to design new sailboats and powerboats or modify existing ones. When you graduate, you'll have the top-level skills you need to launch your career in a design firm, a production boat manufacturing company or even to establish your own design office.

To learn more about Westlawn and our unique distance-learning program, download a free illustrated catalog from our website today, or contact us at: 800.836.2059, 24 hours.

▶ ***Elements of Boat Design Short Course Also Available***

WWW.WESTLAWN.EDU

WESTLAWN Not-for-profit educational affiliate of the American Boat & Yacht Council. ABYC

Westlawn Institute of Marine Technology
16 Deep Cove Road • Suite P • Eastport, ME 04631
PH: 207.853.6600 • FAX: 207.853.6605

***Founded in 1930,** Westlawn is the only nationally accredited distance-learning school of small-craft design in the United States. Westlawn is an accredited member DETC, in Washington DC.*

they might not. According to Wolfe, "Although the stitching usually disappears, sometimes we can spot the needle holes. But not every time."

Emulsion-bonded mat makes laminate differentiation problematic at best. Smashing a sample with a sledgehammer might reveal more about what layers were attached to one another before lamination than a burnout test can. Wolfe noted that it is usually impossible to determine whether a 4-oz/sq-ft (1,200-g/m^2) chop layer was applied as four 1-oz layers (300-g/m^2), double 2-oz layers, or one thick 4-oz layer.

In addition to removing surface coatings, other details of sample preparation are important. The typical ASTM test specifies that the sample be cut into 1-sq-in (6.4cm^2) coupons. Cutting square samples in the field is difficult. You're more likely to send in 2″- to 4″-diameter (51mm to 102mm) holesaw coupons. The ASTM test can reveal the relative orientation of plies within the test coupon. Usually, manufacturers or surveyors want to know whether the laminates are oriented 0°/90° or ±45° in relation to the hull. But, unless you place an orientation arrow on the sample, the lab will not know which way is forward, and fiber orientation data will be compromised.

Even while following that advice, on more than one occasion my orientation indicators have been lost when the sample had its gelcoat sanded off, or was cut to a standard square sample size. One lab I worked with preferred a hacksaw-cut notch in each coupon perimeter, while another lab was fine with a scribed arrow on the sample surface. "At Structural Composites," Wolfe said, "we mark the rim of the crucibles with a dot of high-temperature ink, and then index the sample orientations to the marks. You still have to be careful to avoid rotating the plies relative to those index marks, as the samples are unstacked after burnout."

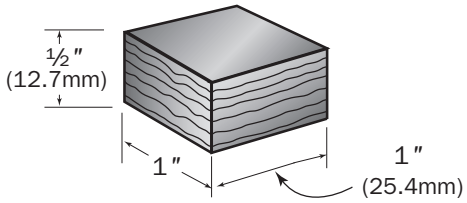
When discussing with the lab how results of a test program should be presented, be sure to specify how you want the laminate weights expressed: in grams per square meter; or ounces per square foot for chopped strand mat and ounces per square yard for long-fiber materials.

Modified Burnout

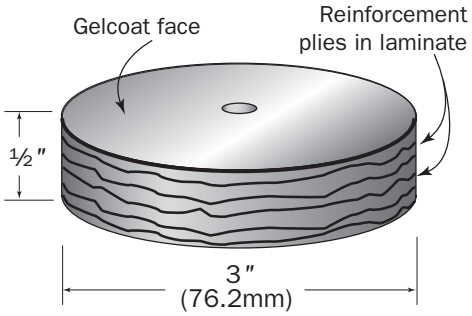
Over the past few years, Art Wolfe and I developed a modified burnout test, which employs a much larger sample—typically a 3″-dia (76mm) holesaw coupon, encompassing approximately 7 sq in (45.2cm^2). Most reinforcement fabrics are referenced in ounces per square yard (1 sq yd = 1,296 sq in). Compared to the ASTM 1-sq-in sample size, a nonstandard 3″-dia sample reduces the extrapolation factor sevenfold, increasing the accuracy of laminate areal weight predictions. I like the improved results I've seen from our modified test; and except for legal work, I'm not concerned about noncompliance with the ASTM standard test method.

One drawback of the modified test is that labs specializing in ASTM testing may have only small crucibles and muffle furnaces for the standard 1-sq-in samples. The labs I work with for the modified test specialize in marine composites. They have much larger crucibles and, as Art Wolfe said, "good exhaust fans to deal with all the smoke generated

ASTM vs. Modified Test Coupon



ASTM 1-sq-in (6.4cm²) sample



A 3″ holesaw cutout encompasses 7-sq-in (45.2cm²) surface area and reduces the extrapolation factor for areal weight predictions sevenfold.

from burning out a two-to-three-inch diameter holesaw coupon."

These modifications to standard tests evolved from collaboration with the labs, and discussion of my frustrations with standardized testing results. Despite the improvements and fine-tuning of the simple burnout and ply-determination test I've described, interpreting the results remains complicated. For instance, the burnout test sample could be taken from a location in the hull with panel overlaps, which increases the ply count, or from sections with relief cuts where a ply might be absent. Whether the sample ply count is truly representative of the overall laminate, or is a local anomaly, must be determined. When in doubt, test more samples.

Note, too, that Kevlar and other aramid fabric laminates cannot be burnout tested, because the fibers melt before the resin disappears. Testing those laminates is a topic for another article. PBB

About the Author: *As "Bruce Pfund Special Projects LLC," Bruce consults on composite processes and inspects marine composite structures. He is the technical editor of* Professional BoatBuilder.

Note: *This article is based on an IBEX '08 seminar whose speakers were Pfund, David Jones, and Robert Lindyberg. Jones, a structural designer, owned and operated a composites testing lab for a number of years; Lindyberg, a composites research expert, manages a major lab at the University of Maine; Pfund, for his part, having sent hundreds of samples to various labs over the years, represented the customer's perspective. While the article focuses on the simple burnout test, discussion of other test protocols will appear in future issues of* Professional BoatBuilder *and on the Web at www.proboat.com—Ed.*