Flying high on composite wings

FRP wings, fuselages and other primary and secondary structures on GA prop, turboprop and jet aircraft help lift this market to unprecedented heights.

By Sara Black | May 2008

Buffeted by boom/bust business cycles and some painful shakeouts for most of the past 50 years, the general aviation (GA) market is currently enjoying an upturn. Sales have been on the rise since 1994, despite a slight retraction from 2001 to 2004, and last year they reached an all-time high (see our GA market report on p. 70). What’s driving the boom? A significant factor is the exponential increase in the number of GA planes made with composites. “Of the 2,675 piston-engine-powered aircraft produced in 2007, 1,376 were made with composite airframes,” says Jens Hennig, VP of operations for the General Aviation Manufacturers Assn. (GAMA, Washington, D.C.). That’s 51.4 percent. A decade ago, less than 5 percent were fabricated with composites.”

Source: Cessna

Much of that increase can be attributed to new certified aircraft manufacturers Cirrus Design Corp. (Duluth, Minn.), Diamond Aircraft (London, Ontario, Canada), Liberty Aerospace (Melbourne, Fla.) and the former Columbia Aircraft (Bend, Ore.), which is now owned by Cessna Aircraft Co. (Wichita, Kan.), all of whom started significant production of composites-intensive aircraft within the last few years. Additionally, Hawker Beechcraft Corp. (Wichita, Kan.) has employed automated advanced fiber placement techniques on its jet fuselage barrels for seven years. Companies that are currently in the process of certifying composite designs for personal/business jets include Cirrus, Diamond, Epic Aircraft (Bend, Ore.), Embraer (Sao Jose dos
Campos, Brazil), Honda Aircraft Co. (Greensboro, N.C.), Spectrum Aeronautical (Carlsbad, Calif.), Farnborough Aircraft Corp. Ltd. (Farnborough, U.K.) and Bombardier Aerospace (Dorval, Quebec, Canada), which is working with partner Grob Aerospace (Zurich, Switzerland) on the new Learjet 85. This list doesn’t include the many kit plane companies who sell composite components for customers to assemble. HPC surveyed a representative group of these manufacturers to get a glimpse of the materials and fabrication methods that are driving this market segment.

A metal-to-composites leap

Known for its all-aluminum aircraft, Cessna became, in late 2007, a full-blown composite aircraft OEM when it purchased the assets of bankrupt Columbia Aircraft. Cessna inherited the composites legacy of aircraft designer Lance Neibauer, who spun off Lancair Certified and later Columbia Aircraft in the 1990s to produce certified aircraft based on his popular experimental kit plane designs. Noted for speed and good looks, the fixed-gear piston aircraft, now dubbed the Cessna 350, and its turbocharged piston sibling, the Cessna 400, have an enthusiastic following in the pilot community: “The 400 is the fastest certified production piston aircraft made. This was a great addition to the Cessna line,” notes Rod Holter, VP/GM of Cessna’s Independence, Kan. plant and interim GM of the Bend facility.

Holter explains that both planes were certified to meet more stringent-than-normal “utility” aircraft category rules under the U.S. Federal Aviation Admin.’s (FAA) Federal Aviation Regulations (FAR) Part 23. Utility-certified planes have to meet a 4.4G positive load factor and 1.76G negative limit load, says Holter, which makes the aircraft more maneuverable, durable and survivable in the event of a crash.

Structural parts for the 350 and 400 are hand layed up using unidirectional and woven prepregs supplied by both Newport Composites and Adhesives Inc. (Irvine, Calif.) and Advanced Composites Group Inc. (ACG, Tulsa, Okla.). Key structural parts, including wing spars, fuselage longerons, horizontal stabilizer, control surfaces and other parts subjected to high loads are made with carbon fiber/epoxy. E-glass/epoxy prepreg makes up the majority of the remaining structure, including the fuselage and wingskins. According to Holter, about 15 percent of each airframe is carbon. All material allowables are company proprietary, says senior project engineer Tom Bowen, meaning the company conducted its own qualification testing rather than relying on prequalified materials (for information about prequalified, see “Learn More”).

The sandwich construction fuselages are fabricated in two halves, right and left, with longitudinal bondlines. Skins are fiberglass/epoxy, and the core is a unique, 3-lb density resin-impregnated aramid paper core, manufactured by Advanced Honeycomb Technologies Inc. (San Marcos, Calif.). Bowen explains that the core material has a unique cell design and a higher density than standard phenolic paper honeycomb core, delivering higher hot/wet compression strength — one of the key elements that ensured “utility” certification.

Source: Cessna

A technician bonds composite components during wing assembly on what is now known as the Cessna 400. Leading GA metal aircraft builder Cessna Aircraft Co. became the fourth largest composites GA planemaker with the acquisition in late 2007 of bankrupt Columbia Aircraft’s assets, which included not only the speedy, turboprop-powered 400 (pictured, top right) but also the piston-powered version, the 350.
The wings are a one-piece assembly with a dual-carry-through spar, explains Bowen, which attaches to the fuselage with mechanical fasteners through a reinforced contoured composite fuselage saddle. The two C-section spars face each other and run the full length of the wing structure. Each spar carries an upper and lower spar cap built up from unidirectional carbon prepreg strips; webs are made with fiberglass/epoxy prepreg over honeycomb core. The upper spar caps, which are in compression during flight, taper from approximately 135 plies of uni carbon prepreg at the root to just two plies at the wingtip. The lower spar caps, in tension, taper from 72 plies at the root to two plies at the tip.

“The wing is a very diverse part because of the complex loads to which it is subjected. The bending moment is very small at the wingtip but ramps up to a substantial load at the root area,” notes Bowen. The cored fiberglass upper wingskin, with its higher compression loads, is a 5/core/2 construction at the root (that is, five skin plies on the upper side of the core layer, two skin plies below), and it tapers to 2/core/2 at the wingtip. The lower wingskin is 3/core/2. Embedded aluminum and copper wire mesh in the skins provides lightning strike protection.

After layup, parts are cured in an oven and then demolded and bonded where required. A second oven cure is required to cure the adhesive. Nonstructural parts, like interior panels, are made either with prepregs or in a wet layup process and are similarly oven-cured.

Source: Cirrus Design

Cirrus Design is currently the largest U.S. general aviation OEM in terms of total composite aircraft deliveries. It’s SR22 Generation Three aircraft is equipped with a parachute safety system.

Bowen notes that production tools at the Bend plant are currently a mixture of aluminum, fiberglass and carbon/epoxy composite: “Columbia couldn’t afford to invest in more expensive high-rate metal tooling.” Bowen and Holter both say that with Cessna’s deeper pockets, it is likely that more robust production tools will be forthcoming, based on ongoing trade studies.

“Composites are the only material that can effectively capture the complex shapes and radically different flowing lines of these planes’ designs,” concludes Bowen. Holter adds that the entire 2008 production quotas of both the 350 and the 400 are sold out, which bodes well for the future.

The lion’s share

The number one general aviation OEM in the U.S. today, in terms of total deliveries of composite-airframe aircraft, is Cirrus Design. The company delivered 710 aircraft in 2007, or 26 percent of the total for piston aircraft deliveries, more than any other manufacturer in GAMA’s database.

Cirrus Design was started in 1984 as a kit plane designer/manufacturer by brothers Alan and Dale Klapmeier. In 1998, the duo certified the SR20, a lightweight, all-composite four-place airplane (see HPC
July/August 1999, p. 9). Today, the company offers the SR20, SR22, a turbocharged version of the SR22, the SRS Light Sport Aircraft model (see “Learn More,” p. 69) and a “personal” jet named the-jet, which is currently undergoing certification. Jay Yeakle, Cirrus Design’s chief of airframe engineering in the company’s advanced development group, says, “Alan and Dale Klapmeier cut their teeth on a Glasair Aviation kit plane before they started the company. Composites are what we know.”

Source: Liberty Aerospace

Liberty technicians lay up carbon/epoxy prepreg for a Liberty XL-2 two-seat, piston-powered aircraft.

The SR22 Generation Three (G3) aircraft is the company’s highest-performance piston-engine offering and its latest design. The majority of the aircraft is fabricated using E-glass/epoxy prepreg, with some S-2 Glass/epoxy prepreg (incorporating S-2 Glass fiber manufactured by AGY, Aiken, S.C.) and carbon/epoxy prepreg used strategically for added stiffness and strength, says Eric Hartwig, chief of materials and process engineering. Glass prepregs are supplied by TenCate Advanced Composites USA (Morgan Hill, Calif.) and are prequalified through the National Center for Advanced Materials Performance (NCAMP) at the National Institute for Aviation Research (NIAR) at Wichita State University. (Cirrus performed qualification and design allowable testing for the TenCate BT250 prepregs, notes Hartwig.) The plane, like Cirrus’ other models, is qualified under FAR Part 23 regulations to “normal” certification standards.

The G3 incorporates a one-piece, monolithic (uncored), autoclave-cured carbon/epoxy C-shaped wing spar that saves 30 lb/13.6 kg over the previous spar design, translating to higher payload and greater range for the G3. The 35-ft/10.7m long spar, approximately 0.5-inch/12.5-mm thick, is produced for Cirrus by Applied Composite Technology (ACT) Aerospace (Gunnison, Utah). The material in the spar is NCAMP-qualified carbon/epoxy prepreg from Toray Composites America Inc. (Tacoma, Wash.), made with Toray’s T700 carbon fiber, says Hartwig. Both a 12K plain weave fabric and a 145 g/m² unidirectional prepreg are used in the spar’s construction, which is in the form of the letter “C,” with the curve facing forward.

“Large area parts” are sandwich constructions hand layed up by Cirrus technicians. The fuselage is split lengthwise into right and left halves that include the vertical tail. Typical construction is 2/core/2, with E-glass/epoxy skins over Divinycell HT (aerospace-grade) closed-cell foam core supplied by DIAB Sales Inc. (DeSoto, Texas). Core thickness is typically 0.4 inch/10 mm. Yeakle explains that the number of skin plies increases as needed in key areas to increase buckling stiffness and strength around penetrations. Plies of uni S-2 Glass prepreg are incorporated into the fuselage roof to form the roll cage structure for rollover protection.

The same materials and methods are used for the wingskins and horizontal stabilizer skins, which incorporate, in selected areas, a surfacing film containing an expanded aluminum mesh for lightning strike protection. Tooling is a mix of billet steel and glass/epoxy and carbon/epoxy composites made with tooling prepregs from ACG.

After oven cure, the large parts are bonded together using PTM&W Industries Inc. (Santa Fe Springs, Calif.) ES6292 paste adhesive — including the fuselage/tail halves, the wingskins (over the spar and ribs)
and the horizontal stabilizer skins. The horizontal stabilizer is then bonded to the fuselage, and the wings are bolted to the fuselage with stainless steel and titanium fasteners. Control surfaces are aluminum, notes Yeakle, and galvanic corrosion is not an issue because no carbon is in contact with the aluminum. Interior panels include natural fiber composite materials from Composite America LLC (Fargo, N.D.).

Approximately 1,700 labor hours are required to produce each SR22 G3 aircraft, which incorporates safety features like the trademarked Cirrus Airframe Parachute System (CAPS). Yeakle attributes the company’s current success and market dominance to continuous improvement: “We don’t allow our designs to stagnate — we’re always striving to make our aircraft better.”

Source: Liberty Aerospace