

Thermoplastic composites for aerospace

PLASTICS IN AEROSPACE

by Michael R. Favaloro

Today's reinforced thermoplastic composites are showing up in more demanding light-weight design aerospace applications thanks to significant advances in innovative technologies and matrix materials.

For example, the new Gulfstream G650 business jet, with its first-of-kind welded thermoplastic composite rudder and elevator tail section, made a successful maiden flight in late 2009. The composite rudder and the elevator were designed and developed to take advantage of a new induction welding method that joins the components into an inseparable unit, which eliminates both cost and weight associated with drilling and riveting or bonding. The high-performance composite parts are based on a polyphenylene sulfide (PPS) matrix and developed in the form of prepregs. The parts remain hard, impact-resistant, stiff and dimensionally stable, even when exposed to elevated temperatures and aggressive fuels, and are 20 percent lighter than those made from traditional materials such as metal and light alloys.

Aerospace industry and composites

- In 1982, 8 percent of the Airbus A130 consisted of composites.
- Twenty years later, the use of composites in the Airbus A380 rose to 25 percent.

- In the next generation of aircraft, the use of composites is expected to hit 50 percent — Airbus A350 will be 53 percent composite and Boeing 787 will be more than 50 percent composite.

The incorporation of light weight plastic and composite materials in commercial aerospace vehicles is becoming a common design practice for reducing vehicle weight and achieving fuel savings. Early aircraft interior cabins were typically sheet metal, with any number of fabrics, foams and plastic materials in different locations. Today, metallic structures are being replaced by composites for vehicle weight reduction and resultant fuel savings.

The vast majority of composite materials for aerospace are based on thermoset materials, especially in the United States. However, thermoplastic composites have been used for several years in Europe on the Airbus A340 and A380. Some thermoplastic composite parts on these vehicles include the fixed wing leading edge, keel beams and other components. For the most part, though, exterior aerospace components in Europe are based on thermoset composites, and in the United States there is yet to be one thermoplastic based composite in large commercial aircraft exterior structures.



Carbon/Fortron® polyphenylene sulfide (PPS) composites are used in patented lightweight modular passenger seat frames manufactured by Cutting Dynamics Inc.

The focus on thermosets by the commercial aerospace composites industry exists for a number of reasons:

- Thermoset composites have a successful track record dating back to the 1960s, making the knowledge database very mature.
- Substantial investments in thermoset composites have been made in the United States for design tools, material property databases, capital equipment, employee training, test methodologies, making a mature material value chain.
- Conversion to alternate materials and processes require substantial reinvestment and requalification costs as well as retraining of engineering and manufacturing personnel.

Since thermoset composite processes and materials are mature, cost and weight reduction associated with design optimizations are less likely to continue. As a result, it becomes difficult to meet the needs of an evolving aerospace environment with fixed structural costs. Reinforced thermoplastic composites offer the aerospace industry opportunities to achieve weight and cost savings as well as a green solution vs. thermosets.

Thermoplastic vs. thermoset

A rational justification can be made for using higher-cost thermoplastic composites instead of thermoset composites in aerospace applications.



Fortron® based PPS composites are used in demanding aerospace applications like this Airbus A380 leading edge. It was selected for its low cost and excellent performance in this critical environment.



From a material side, thermosets are cross-linked when heated and cannot be re-melted or re-formed, while thermoplastics are melt processable polymers that provide a more tailorable and more forgiving process. For example, thermoplastics are heated, melted or softened, reshaped, and then cooled to a final hardened shape, making them easy to re-work and repair.

The raw materials in thermoplastics also have a near infinite shelf life and cost less to store than thermosets, which have a typical shelf life of less than six months and require costly refrigeration, tight schedule control of material receipt and conversion to final form.

In addition, thermoplastics:

- Are typically four-times tougher than comparable thermosets, which results in more impact resistance and damage tolerance.
- Are relatively insensitive to aircraft fluids and chemical attack, and with one exception, insensitive to moisture.
- Offer substantial reductions in flammability, smoke and toxicity performance, which is of major importance in manned aircraft.

From a processing standpoint, some of the existing and expensive equipment used by the industry to process thermoset composites, such as autoclaves, could be used for thermoplastic processing. However, the relatively slow and inefficient process times required for heat up and cool down would reduce process and cost efficiency options associated with thermoplastics.

Typically, thermoplastics are heated, formed and cooled rapidly, while thermosets must be held at temperature for tens of minutes or hours to achieve cure. The net result is a significant savings in process energy cost for thermoplastic composites. Thermoplastic processes also



A high-quality carbon composite tape made with Fortron® polyphenylene sulfide (PPS) is taking the weight out of braided preforms manufactured by A&P Technology Inc. for advanced aircraft interior applications.



Gulfstream G650 business jet with its first-of-kind welded thermoplastic composite rudder and elevator tail section based on a Fortron® polyphenylene sulfide (PPS) matrix developed by Royal Ten Cate.

eliminate associated material bagging and labor costs as well as the need for in-line consolidation techniques, kitting and debulking steps and equipment.

Thermoplastics and their associated processing innovations eliminate the need for autoclave processing, which in turn reduces capital cost, floor space requirements and processing bottleneck issues.

As a green solution, the processing of thermoplastics vs. thermosets cannot be overstated. Thermoplastics can, by definition, be fully recycled, and little to no volatile organic compounds (VOCs) are released during processing. Process scrap can also be reduced substantially with existing fiber placement technology.

Aerospace grade thermoplastic options

Three thermoplastics are available for use by the aerospace industry — polyphenylene sulfide (PPS), polyetherimide (PEI) and polyetheretherketone (PEEK).

PEEK

The best known representative of the high-temperature resistant thermoplastics — melting point is 335°C (635°F) — is PEEK. Applied in the industry for more than 20 years, it offers the most extensive commercially available data, and is considered the baseline for aerospace grade thermoplastic composites.

PEEKs are resistant to virtually all organic and inorganic chemicals. They are also resistant to hydrolysis up to about 280°C (536°F). On the other hand, they are not resistant to ultra-violet (UV) radiation, concentrated nitric acid, general acid-oxidizing conditions and some halogenated hydrocarbons. There are several suppliers of PEEK resin in the industry,

but it is one of the most expensive engineering plastics.

PEI

PEI is a high-performance thermoplastic that belongs to the high-temperature-resistant plastics group — up to about 200°C (392°F). It is inherently flame-retardant with low smoke development. It is used as a composite matrix in numerous aircraft interior structures, including floor panels, pressure bulkheads, and other components. Unfortunately, PEI is susceptible to attack by anti-icing fluids, which prevents extensive use in aircraft exterior applications.

Even in the unreinforced state, it has very high strength, which can be further increased by the addition of glass or carbon fibers. PEI has high dielectric strength, is resistant to hydrolysis and very resistant to UV and gamma rays.

continued on the next page



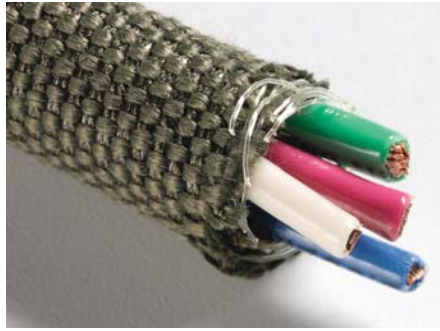
Carbon/PPS keel beam rib for Airbus A340.

PPS

This polymer is the lowest cost of the three thermoplastics available for use by the aerospace industry. Successful application of PPS composites in aircraft include the undercarriage door for the Fokker 50, fixed wing leading edges for the Airbus A340 and A380, keel beams, brackets and others.

Not only is this high-performance thermoplastic extremely strong, rigid and tough, it offers inherent flame resistance, high heat resistance with continuous service at temperatures well above 200°C (392°F). It also has very good chemical and oxidation resistance, minimal water absorption, good electrical properties, low creep and excellent mechanical properties.

These three candidate resins — PEEK, PEI and PPS — are finding increased use in commercial aerospace applications. While the long-term investment into the higher performance PEEK material has resulted in a good database and flight history of the material, investments continue to be made in both the PEI and PPS databases and processes, which is leading to increased use as their cost effectiveness becomes documented. As these resins receive more industry acceptance, the cost reduction curves for all aerospace composite materials are expected to improve.



Aircraft cable sleeve manufactured from Fortron® polyphenylene sulfide (PPS) monofilament for its flame resistance, wear resistance and high temperature performance.

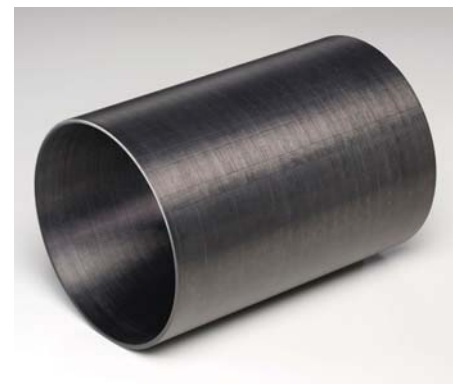
Weight reduction tilts advantage to thermoplastics

Load-bearing aircraft and aerospace structures are being replaced by thermoplastic composites. Lighter airliners significantly reduce fuel and operating costs, and are crucial to economic success.

Composites are conquering traditional metal domains throughout the aircraft. They've reached such an advanced stage of development that some complex thermoplastic components would actually be impossible to produce in metal. Even if these parts could be made in metal, the costs would be prohibitive.

Today, 1,000 components on the Airbus A380, weighing more than 2.5 tons, are produced from composites with a PPS matrix. This high-performance composite material is used in exterior components such as wing leading edge noses, or ribs and stiffeners that strengthen the fuselage. Interior applications include the lumbar support made from carbon-fiber reinforced composite, which is integrated into the seat back. Compare its 150 grams to a comparable support in aluminum that weighs in at 280 grams — nearly twice as much.

And, in the near future, patented thermoplastic modular composite seat frames for passenger seat assemblies will be installed to help reduce weight and cost even more. These seat frames are made from PPS thermoplastic resin that is combined with carbon fiber to make a low-cost tape. The tape is slit in nominal widths and braided, and used to create high quality unidirectional preform blanks, which can be readily molded into specific shapes and consolidated into unique final shapes in a matter of minutes.



Carbon/PPS composite cylinder manufactured by Automated Dynamics, using the fiber placement process.

The new carbon/PPS composite seat frames weigh much less than their aluminum counterparts while meeting high torsional load requirements. They also meet U.S. Federal Aviation Administration flame smoke and toxicity requirements, which thermoset composite seat frames can no longer meet. ■

Michael R. Favaloro is Ticona technical marketing manager — Fortron® PPS Composites — Americas. He may be reached at e-mail: michael.favaloro@ticona.com. For more information, contact Ticona, 8040 Dixie Highway, Florence, KY 41042 USA; (800) 833-4882 www.ticona.com/composites.



Take your **KNOWLEDGE** to the next level — level two.

ARE YOU READY? IAPD has launched level two of the IAPD Plastics Certificate program! Level two puts all the information learned in level one — plastics materials and properties — to practical use with applications from a variety of markets. Be one of the first to pass the test! Apply today!

Although it comes in the form of a test, it's meant to serve as a learning tool. It evaluates your ability to help your customer by providing customer service solutions. You will not always know all of the answers, but in order to be a successful distribution professional, you must know where to find them. This test gives you the practice to help you accomplish that goal.

Candidates must currently be employed within the plastics distribution industry and must also adhere to the IAPD Code of Ethics, available at www.iapd.org. Level two candidates must have also successfully passed the level one certificate program.



Contact IAPD for more information.
Call +913.345.1005 or visit www.iapd.org.