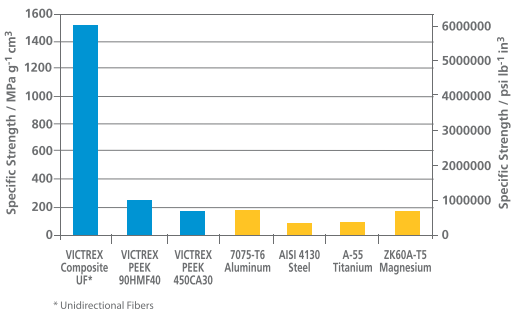
PEEK system solutions for lightweight aerospace components and assemblies

by Richard Leibfried and Michael Sandeen

Polymers play a vital role in many aerospace applications where engineers require lightweight materials that offer processing flexibility, reduce manufacturing costs, and provide durability in harsh environments. The industry's trend toward higher temperatures and higher loads in mechanical systems requires high performance polymers that can meet the demand for weight reduction, increased efficiency, noise reduction, miniaturization and functional integration — all at a reduced cost.

Polymeric advantages

In recent years, PEEK, a high-performance thermoplastic polymer, has been increasingly specified to replace metal in aircraft components including wing, engine and fuel systems. It has effectively replaced aluminum, titanium, magnesium, bronze, corrosion-resistant (CRES) or stainless steel and specialty alloys because of its unique combination of mechanical, thermal and tribological properties combined with excellent chemical resistance and electrical performance. These polymeric advantages translate into improved efficiencies both in terms of aircraft weight and ease of manufacturing. Designers have greater freedom to combine multiple components into a lighter single part with better uniformity. Lightweight components can also offer easier manufacturing assembly, shorter cycle times, and overall reductions in aircraft operating costs.



Specific strength of VICTREX® PEEK™ polymer-based materials in comparison with other common aerospace materials.

PEEK POLYMER ADVANTAGES

- Lightweight material solutions
- Strength and durability in harsh environments
  - High temperature performance
  - Chemical resistance
  - Mechanical strength
- Processing flexibility
  - Miniaturization
  - Functional integration
- Reduced manufacturing costs

Performance benefits

As a lightweight solution, materials based on PEEK polymers have successfully displaced metals, traditional thermoset composites and other plastics because they are exceptionally strong, inert, inherently heat and flame resistant, and easily fabricated into tight tolerance parts. Metal parts' replacement and conversions of metals to PEEK can provide a number of performance benefits including:

• **High temperature resistance** — Many aerospace components must endure continuous long-term exposure to elevated temperatures. Because of its semi-crystalline structure, PEEK maintains its mechanical properties well past the glass transition temperature (T_g). PEEK polymer has a relative thermal index (RTI) of 260°C (500°F).

• **Flammability** — PEEK performs exceptionally well in respect to flammability (FAR25.853 and 25.856 compliance). The material is UL94 V-0 rated at 1.5 mm and has a limiting oxygen index of 35 percent at 3.2 mm (0.13 in) thickness and 24 percent at 0.4 mm (0.02 in) thickness. These flammability characteristics are inherent in the material and are achieved without the inclusion of any flame retardant materials such as halogen-based additives.

• **Toxic gas emissions** — When combustion does occur, the generation of smoke and toxic gases can present major hazards. PEEK produces very little toxic gases when combusted. It produces mainly carbon dioxide and carbon monoxide upon pyrolysis. PEEK has a toxicity index of 0.22 (MOD NES 713) with no acid gases detected.

• **Chemical resistance** — In addition to high temperature and flammability performance, aerospace polymers must maintain their properties in extreme chemical environments. PEEK has exceptional resistance to a wide range of acids, bases and hydrocarbons including jet fuel and hydraulic fluid.

Availability and qualifications

PEEK is available in a range of grades and compounds to maximize mechanical properties and capitalize on its versatile processing characteristics. It can be converted into finished forms such as stock shapes, compression and injection molded parts, films and coatings. In addition, PEEK can be used in thermoplastic composite prepreg structures forming a matrix with carbon, glass or aramid continuous fibers.

PEEK-based products have been officially qualified by many aircraft manufacturers and can also be supplied to military specification MIL-P-46183. The ability to reduce weight is especially attractive to the defense industry where specifying PEEK has allowed engineers and designers the freedom to innovate with radomes, ordnance and unmanned aerial vehicles (UAVs).

PEEK system solutions

When designing aircraft systems for exterior and interior applications, engineers have stringent material requirements. Exterior applications require stability at high temperatures with prolonged exposure to moisture, chemicals and constantly fluctuating loads. Interior applications require high stiffness and strength-to-weight ratio, creep and chemical resistance, low CTE and FAA flammability. PEEK's durability, flame retardance and low smoke and toxicity serve to enhance interior applications, while PEEK's chem-

ical and ozone resistance, as well as its thermal properties and impact resistance contribute to its success in exterior applications.

Hubcaps for landing gear — Boeing 777 aircraft are equipped with a tire and brake monitoring system, which includes active pressure sensors and transmission of real-time data to the cockpit. The system specifies PEEK for the hubcap because of its high temperature performance, mechanical strength and chemical resistance to the caustic elements found on the runway. Aircraft landing gears must survive some of the most extreme environments and loading conditions making PEEK a good replacement to previously used aluminum.

Electric wire bundle and tubing clamps — Incorporating PEEK polymer in electric wire bundle and tubing clamps results in weight reduction, part consolidation, design scalability, chemical resistance and fatigue performance. Currently, a range of PEEK tubing clamps overmolded with a silicone rubber cushion deliver significant weight and cost savings on the new Boeing 787 aircraft.

Pipes and convoluted tubing — For convoluted tubing, PEEK offers a solid, yet flexible barrier to chemicals and moisture with lighter weight and better crush and abrasion resistance. Rigid PEEK pipes can be extruded in a range of sizes and material formulations for specific applications including fuel, hydraulics, water and drainage.

Door handles— On the Airbus A380, lighter weight was paramount for the aircraft's door handles, which were previously made in die-cast metal. PEEK provided the higher specific strength and highest modulus when compared to traditional materials of construction such as aluminum. The two-piece door handle components are injection molded and have complex geometries with numerous ribbing and long flow paths. PEEK was the only material to have survived the Airbus test program for door handles.

VICTREX® PEEK™ polymer was specified in the Boeing 777 landing gear hubcaps due to its high temperature resistance and mechanical strength.

Impeller blades — PEEK has been used to replace metal propellers and impellers in a range of aerospace devices, including oil cooling systems and ventilation system fans used for low pressure air delivery in helicopters. They can be designed to weigh much less than metal components, have less inertia and reduce the horsepower requirements of the motors used to spin the blades. Using PEEK allows the wall section and mass of the impeller housings to be significantly downsized.

Insulation film coverings — Insulation materials have evolved significantly over the past decade driven by more demanding FAA regulations and weight reduction initiatives. Airframe makers and film laminators have worked closely together to supply very thin PEEK-based film for the covering of thermal acoustic blanket (TAB) insulation. The new class of insulation film covering offers a 50-60 percent weight reduction versus traditional PVF (polyvinylfluoride).

RFID tags — PEEK-based film is used to encapsulate RFID tags to protect the small components from aggressive environments. It provides an excellent combination of friction and wear properties combined with high heat resistance, chemical and radiation resistance, purity, electric insulation and radio-wave transparency.

Fasteners — While aircraft structures made of lightweight composite materials are becoming standard for new aircraft development, joining these structures is too often done with standard metal fastening systems that add unwanted weight. A composite material made of continuous fiber reinforced PEEK is filling the gap with truly lightweight fastening systems, bolts, nuts, inserts and brackets. Made from a pultruded PEEK profile the fasteners can be bolted traditionally, or friction welded directly into other PEEK including molded parts/inserts, composite laminate panels, or even PEEK honeycomb sandwich structures, providing increased impact resistance and fatigue strength. These composites have a static strength comparable to high tech aluminum alloys and fatigue properties of titanium alloys. PEEK fasteners can offer electrically insulating or electro-static dissipative (ESD) qualities in structural systems requiring careful management of lightning strikes and electrical interference. This is an excellent example of how PEEK system solutions can reduce weight, total part count, and assembly labor as OEMs strive toward lean manufacturing.

Due to its superior strength and ability to reduce overall weight, VICTREX® PEEK™ polymer was chosen for high performance wiring, cable and hydraulic tubing clamps.

Conclusion

PEEK is regarded as one of the highest performing thermoplastic polymers in the world. It has successfully displaced metals, traditional thermoset composites, and other plastics in a growing number of aerospace applications because it is exceptionally strong, inert and flame retardant, and it can be easily fabricated into tight tolerance parts. It provides a specific strength similar to aluminum from subzero temperatures to over 300°C (572°F) and chemical resistance superior to titanium and aluminum. Several processing options exist for PEEK materials to be converted into high performance components that are cost competitive with machined and cast metal parts. PEEK is helping to improve application performance, realizing greater design freedom and achieving system cost savings. ■

Richard Leibfried is market development manager for Victrex Polymer Solutions and Michael Sandeen is technical & product leader, Americas for Victrex Polymer Solutions. For more information, contact Victrex Polymer Solutions, 300 Conshohocken State Road, Suite 120, West Conshohocken, PA 19428 USA; (800) VICTREX, (484) 342-6001, fax (484) 342-6002, e-mail: americas@victrex.com, www.victrex.com.