

10 EMERGING TRENDS IN AEROSPACE PLASTICS AND COMPOSITES



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Aerospace engineers are working on a number of important initiatives including reducing weight, enhancing passenger safety, and creating more sustainable designs. Achieving these goals will require cutting-edge materials with the right combination of properties, manufacturability, and cost.

Since the inception of the aerospace industry in the early 20th century, materials technology has played a key role in aircraft design. Today, aerospace engineers are working on a number of important initiatives including:

- Creating aircraft with lower operating costs
- Reducing weight without compromising performance
- Enhancing passenger safety
- Creating more sustainable designs
- Expanding the range of all-electric aircraft
- Designing new unmanned aerial vehicles for both civilian and military applications
- Driving advancements in space technology

Achieving these goals will require cutting-edge materials with the right combination of properties, manufacturability, and cost to make these new designs possible. The purpose of this article is to discuss 10 trends in plastics and composites that are enabling the aerospace technologies of the future.

POLYIMIDE COMPOSITES FOR HIGH SERVICE TEMPERATURES

Recent advances in jet propulsion technology allow aircraft engines to operate at higher temperatures for increased fuel efficiency during flight. However, higher engine temperatures are challenging for the plastic materials that have traditionally been used for applications including duct seals, spline adapters, locking fasteners, bearings, variable stator vane bushings, and thermal isolators that operate in close proximity to aircraft engines.

Polyimide plastics formulated with low friction additives are seeing increased use for elevated temperature applications that involve friction and wear. For example, DuPont™ Vespel® SCP-5050 is a polyimide copolymer with proprietary fillers that enhance its thermal and tribological characteristics. This material has superior performance when compared with traditional graphite-filled polyimides in laboratory testing that simulates variable stator vane wear for 500,000 cycles at 650°F. Vespel® SCP-5050 has the added advantage of having a thermal expansion coefficient close to those of aerospace metals, minimizing the design issues associated with thermal expansion mismatch.



Variable stator vane bushings made from Vespel® SCP-5050 allow for extended service life in jet engines.

High strength reinforced polyimide composites such as DuPont™ Vespel® CP-0301 are manufactured via sheet molding processes. This class of composite materials offer significant performance advantages for elevated temperature jet engine systems including:

- Outstanding TOS (thermo-oxidative stability)
- High specific strength and specific modulus
- Resistance to creep and stress relaxation
- Vibration damping characteristics
- Fatigue resistance

The jet engine clamp shown below was molded from Vespel® CP-0301, a carbon fiber-reinforced polyimide sheet molding compound which can operate at temperatures exceeding 650°F in some applications.



Lightweight engine clamps made from Vespel® CP-0301 can operate reliably at elevated temperatures.

The high strength to weight ratios of these composites make them attractive alternatives to metals for applications where weight savings is desirable. Figures 1 and 2 below show the high specific strength and specific modulus of Vespel® CP-0301 compared with 6061-T6 aluminum.

Figure 1: Specific Strength (kpsi/lb/in³)

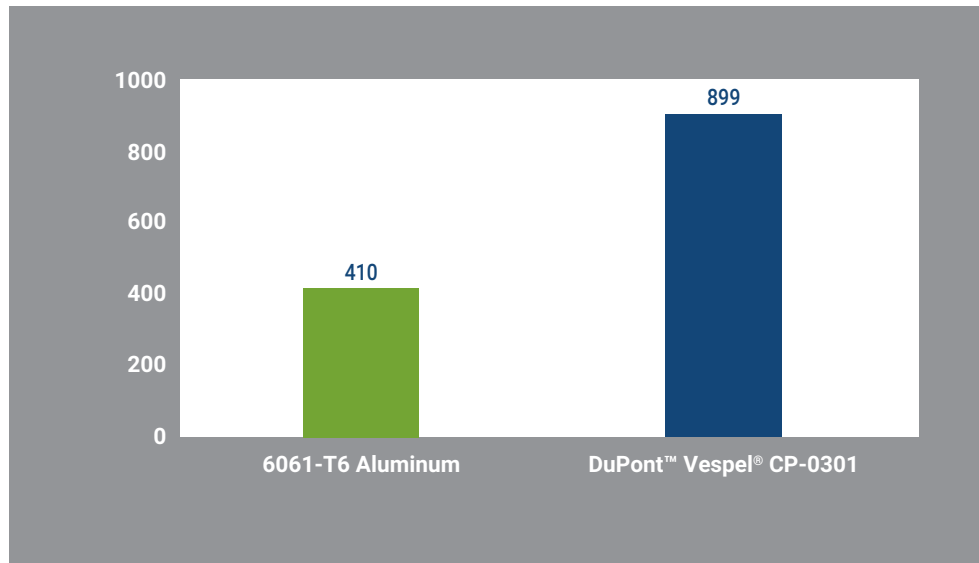
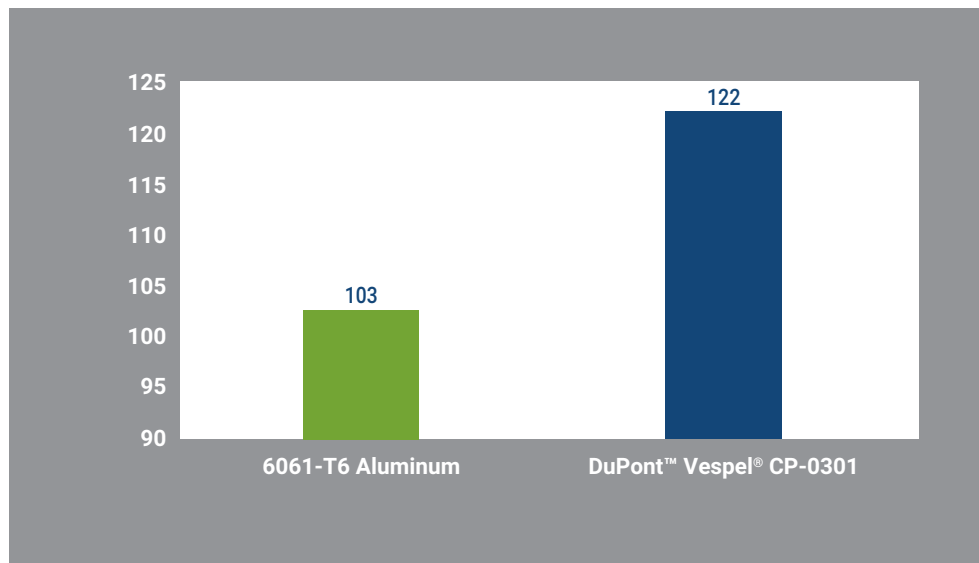


Figure 2: Specific Modulus (Mpsi/lb/in³)



Reinforced polyimide composites such as Vespel® CP-0301 have high specific strength and high specific moduli, allowing for strong, lightweight aircraft components.

ADVANCED THERMOPLASTIC COMPOSITES

New thermoplastic composites represent a significant advancement in material science with specific strength and specific modulus values far above those of traditional reinforced thermoplastics. Examples of advanced thermoplastic composites include DuPont™ Vespel® CR-6120 carbon fiber-reinforced PFA, Ensinger's TECATEC® composites, and Mitsubishi's KyronTEX® and KyronMAX® materials. Figures 3 and 4 below show the mechanical properties of KyronMAX® S9230 and TECATEC® PPS CF50 T200 compared with 6061-T6 aluminum, 30% glass-filled polyamide and 30% carbon fiber-filled PEEK.

Figure 3: Specific Strength (kpsi/lb/in³)

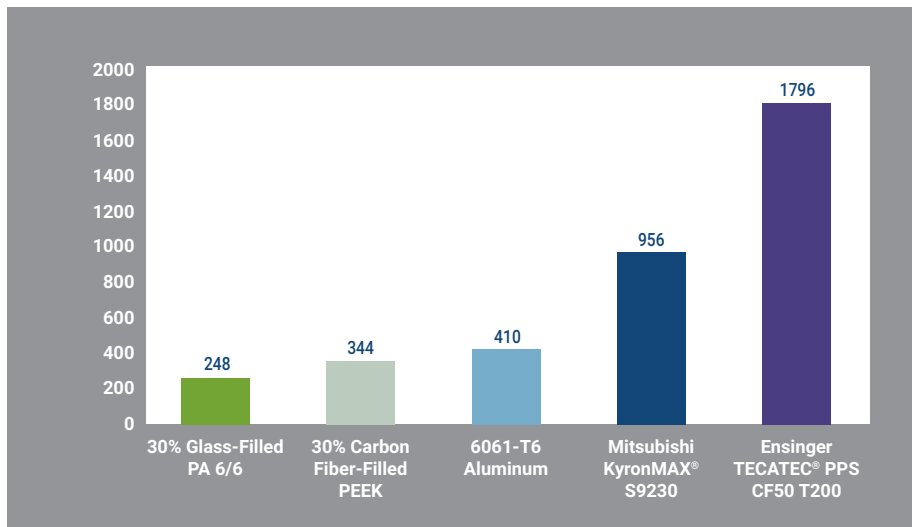
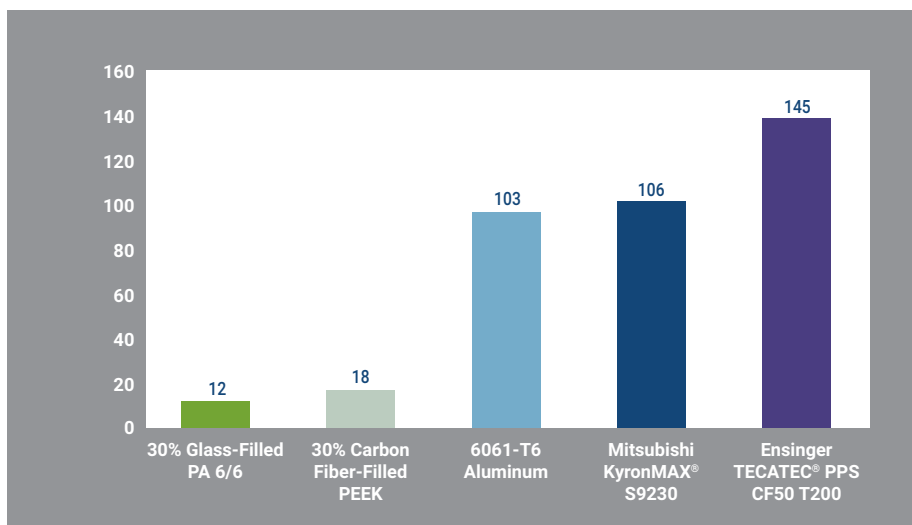


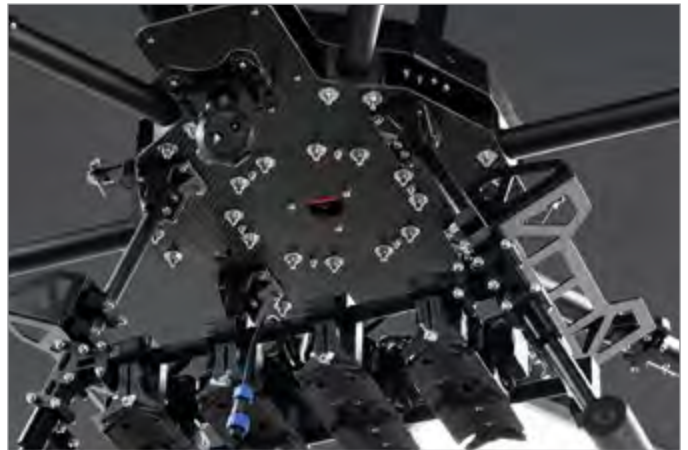
Figure 4: Specific Modulus (Mpsi/lb/in³)



Advanced thermoplastic composites have high specific strength and specific modulus, making them excellent choices for many aircraft applications where light weight and high strength are required. Note: Properties measured parallel to the reinforcement.

KyronMAX® materials are manufactured via injection molding and KyronTEX® composites are formed via a modified compression molding process. Both of these processes have shorter manufacturing cycle times compared with fiberglass layup or machining from stock shapes.

KyronTEX® composites can be molded into high strength aerospace parts with extremely thin walls, which makes these materials a good choice for applications such as drone housings where rigidity and thin part walls are required. Large parts with thin walls are difficult to achieve using traditional thermoplastic molding processes.



Mitsubishi's KyronTEX® materials can be formed into high strength parts with thin walls. KyronTEX® can be considered for drone applications, where stiffness and light weight are important.

THERMOPLASTICS REPLACING METALS IN AIRCRAFT ASSEMBLIES

High performance grades of polyamide, PPE, PPS, Ultem™, PEEK, and Torlon® are increasingly being specified as alternatives to metals for aerospace components. Plastics offer a number of advantages over metals when used in aircraft systems including:

- Reduced weight
- Superior friction and wear characteristics
- Reduced abrasion on mating parts
- Electrical isolation
- Noise and vibration damping properties
- Corrosion resistance
- Low thermal conductivity

Aerospace applications where thermoplastics are displacing metals include wear pads, bearings, bushings, and thermal isolators.



Bushings made from high performance thermoplastics are increasingly being used instead of metals when weight savings, noise reduction, and low wear on mating parts are required.

SUSTAINABLE AEROSPACE POLYMERS

Sustainability has become a focus of the aerospace industry in recent years, particularly for manufacturers and operators of commercial passenger aircraft. The plastics industry has responded to this need with formulations that are either 1) easily recycled at the end of their service life or 2) made using recycled resins. For example, Sekisui's KYDEX® 5555RCL sheet is used for non-aesthetic aircraft interior components. This material has 50% to 100% recycled content in its formulation and it meets a number of stringent flammability requirements for aerospace applications.

Mitsubishi's Sterra® family of engineering thermoplastics includes PET, acetal, and PEEK materials with 25% to 100% recycled resin content, resulting in a dramatically reduced carbon footprint. Sterra® materials are displacing traditional virgin thermoplastics for applications where the properties of high performance plastics are required and increased sustainability is desirable.

HIGH PERFORMANCE INSULATORS FOR ELECTRICALLY POWERED AIRCRAFT

Battery powered planes are replacing traditional liquid fuel powered aircraft for short passenger flights. The range of all-electric planes is expected to increase as new technology allows batteries to achieve higher power densities. The electrical systems for battery power aircraft require high performance plastic insulators to insure safety and reliability. Electrical connectors for these systems are frequently fabricated from plastics with high dielectric strength, dimensional stability, and high operating temperature capabilities including Ultem™, PEEK, Torlon®, DuPont™ Vespel® SP-1, and Vespel® SCP-5000.



Ultem™, PEEK, Torlon®, Vespel® SP-1, and Vespel® SCP-5000 are often used for high performance electrical connectors.

PLASTICS WITH ENHANCED FLAME, SMOKE, AND TOXICITY (FST) PROPERTIES

Aircraft components often need to meet strict flame, smoke, toxicity, and heat release standards including United States Federal Aviation Regulation 25.853, Airbus Standard ABD 0031, and Boeing Safety Standard 7239. The thermoplastic sheet materials used for interior components such as tray tables and arm rests for aircraft seating are formulated to meet these standards. Engineering plastics, for use in non-aesthetic applications such as bushings, housings, and electrical components, have recently been introduced that meet stringent aerospace flammability standards. Examples of these include Ensinger's TECANYL® VH2 Black aerospace-grade PPE and Mitsubishi's Nylatron™ FST PA66.

PLASTICS FOR SPACECRAFT APPLICATIONS

The spacecraft industry in the United States is growing rapidly due to increasing demand for launch vehicles, low earth orbit satellites, and deep space exploration equipment. The harsh conditions associated with spaceflight and the requirements for light weight and reliability can in some cases exceed the limitations of traditional materials. The performance characteristics required for spacecraft applications may include:

- Light weight
- Resistance to erosion from atomic oxygen
- Resistance to degradation from radiation
- The ability to operate at extreme temperatures (both hot and cold)
- Low outgassing in vacuum
- Low friction and a low wear rate
- Some degree of compatibility with spacecraft chemicals including LOX and GOX
- Electrical insulating characteristics
- Dissipation of electrical charge

The plastics industry has thermoplastics, thermosets, and composites formulated for use in spacecraft applications including Ultem™ PEI, PEEK, Torlon® PAI, and DuPont™ Vespel®. Applications for these materials include seals, bearings, thermal insulators, and electrical insulators.



Engineering plastics with low outgassing, wide operating temperature ranges, and resistance to radiation and erosion from atomic oxygen are used for state-of-the-art satellites.

ADVANCED POLYMER FOAMS

The aerospace industry continues to move toward lighter weight materials to improve fuel economy and reduce operating costs. Advanced polymer foams can often replace traditional honeycomb and fiberglass structures, achieving significant weight savings without compromising aesthetics, safety, or performance. For example, Zotek® F OSU XR is a rigid cross-linked closed-cell PVDF foam that is inherently flame retardant and able to perform at elevated temperature due to its fluoropolymer base resin. This material can be molded to complex part geometries, resulting in up to 70% weight savings compared with traditional solid thermoplastics.

LAST-A-FOAM® FR-3700 is a rigid, closed-cell flame-retardant polyurethane foam formulated for outstanding machinability into complex parts. This material is available in grades and sizes that meet FAR 25.853 and Boeing Material Specification BMS 8-133. LAST-A-FOAM® FR-3700 is often used for aircraft interior applications such as seating components and decorative interior trim where weight savings and flame resistance are required.

DuPont™ Vespel® SF polyimide foams represent a significant advancement in cellular plastics technology. These high performance materials are capable of operating at temperatures up to 300 degrees C. They are flame-resistant and they do not release toxic fumes when exposed to open flames. Vespel® SF polyimide foams can be used for a wide range of aerospace applications including acoustic dampers, thermal insulators and abradable seals.



Aerospace-grade rigid polymer foams are seeing increased use for applications where light weight, thermal insulation, and acoustic insulation are required.

RF TRANSPARENT PLASTICS FOR AIRCRAFT RADOMES

Communication systems for military and civilian aircraft, spacecraft, and unmanned aerial vehicles must maintain signal integrity for reliable performance. The plastics used for the radomes that protect antennas have to be engineered to minimize RF attenuation and distortion. High performance thermoplastics such as Tefzel® ETFE have dielectric constants (Dk) and dissipation factors (Df) lower than traditional fiberglass materials across a broad range of frequencies. Tefzel® has the added advantages of outstanding weatherability as well as resistance to incidental contact with many aircraft fluids.

Thermoformable plastic sheet materials such as TUFFAK® SL polycarbonate and KYDEX® 510 can be easily molded into radomes with deep cavities. These materials have the advantages of impact strength and outdoor weatherability.

Foams including LAST-A-FOAM® RF-2200 polyurethane, Plastazote® HD115 polyethylene, and Vespel® SF polyimide can be used for lightweight, RF transparent structures inside of aircraft radomes.



The plastics and composites used for aircraft radomes must have low dielectric constants and low loss factors to minimize attenuation of RF signals.

INTERIOR PROTECTION SYSTEMS TO IMPROVE MANUFACTURING EFFICIENCY

The process of building out the interior of an aircraft involves complex assembly of electrical wiring, flooring and wall systems, light fixtures, galleys, lavatories, overhead bins and seating. The installation of multiple assemblies over a period of months, can result in damage to the aesthetic interior surfaces of aircraft, resulting in expensive rework and repair.

Aerospace manufacturing engineers utilize plastic shields, guards, and masking to reduce manufacturing costs and maintain the quality of aircraft interior surfaces. Selecting plastics for aircraft interior protection can be somewhat complex. Depending on the application, the performance requirements for protective materials might include:

- Lightweight for easy handling by operators
- ESD to prevent electrical discharge
- Non-marking when contacting aesthetic surfaces
- Fire retardant properties, especially if the protection systems will be left in place during test flights.

CONCLUSION

The purpose of this white paper has been to highlight some recent trends in the plastics and composites used for aerospace applications. To learn more about the plastics used in the aerospace industry, please visit Curbell Plastics' website www.curbellplastics.com.

TECHNICAL EXPERTISE

Curbell white papers are intended to provide engineers and designers with basic information about the engineering polymers available as sheet, rod, tube, and film stock from Curbell Plastics. We invite you to contact Curbell via e-mail at technicalsupport@curbellplastics.com to discuss applications in detail.

ABOUT CURBELL PLASTICS

For more than 80 years, Curbell Plastics has been one of the nation's leading providers of plastic sheets, rods, tubes, and films, as well as fabricated parts, adhesives, and prototyping materials. Our customers range from small local businesses to large *Fortune* 500 companies and government agencies. We partner with organizations in dozens of industries, including aerospace, pharmaceutical, machinery manufacturers and sign fabricators. At Curbell, we understand the unique demands of each market and we have the expertise to help you meet your business needs. Whether your objective is to reduce manufacturing costs, improve productivity, or increase product reliability, Curbell can help.

ABOUT THE AUTHOR

Dr. Keith Hechtel is Vice President of Business Development & Marketing for Curbell Plastics. Much of his work involves helping companies to identify plastic materials that can be used to replace metal components in order to achieve quality improvements and cost savings. Dr. Hechtel has over 35 years of plastics industry experience and he is a recognized speaker on plastic materials and plastic part design.

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