Hybrid molding technology supports polymer structural components

By Rob Mazzella

Designing with metals includes extra weight, excessive waste, and manufacturing efficiency challenges. As aircraft manufacturers focus on improving fuel efficiency and reducing overall costs by removing weight and improving time-to-market, the specification of metals can be counterproductive. Victrex polyaryl-etherketone (PAEK)-based composites have been effective in addressing these challenges.

Continuously-reinforced PAEK-based composites deliver up to 70% weight savings and chemical resistance while providing up to 5x greater mechanical properties than metals.

In addition, the thermoplastic enables design and manufacturing improvements, matches thermal and impact resistance of typical metals, and brings thermal insulation and vibration/noise damping benefits.

**PAEK composites vs. thermosets**

Thermosets have long been the industry standard when it comes to composite solutions, but the tide is turning. A PAEK-based solution is able to capitalize on the challenges thermosets present by delivering improved chemical and impact resistance; fatigue performance; and flame, smoke, and toxicity (FST) performance in structural components. While the stiffness, strength, and thermal expansion properties may be similar, thermoplastic composites...
Joining technologies
Victrex PAEK-based composites offer inherent strength and processability while keeping weight to a minimum. The bracket pictured on page 59 provides significantly better mechanical properties than aluminum, titanium, and steel and is up to 70% lighter. Given these benefits, design engineers are looking to use these material solutions for large structural parts. Thermoplastic PAEK-based composites lend themselves to ultrasonic, laser, fillet, induction, and resistance welding.

In addition, thermoplastic composite components can be mechanically joined or even bonded with adhesives so long as the surface has been properly treated.

The nature of the adhesive bond formed between the composite and the overmolded material can be seen in the micrographs in Figures 1a & 1b on page 56. On the composite surface, one can see bare carbon fiber with the surface layer of resin transferring to the overmolded material. The three-dimensional nature of the overmolded surface shows that some material has also been transferred to the surface of the composite. The failure surface is therefore very complex, and the line of failure runs through both the composite and the overmolded material.

Figure 2: Changes in properties for standard Victrex PEEK injection molding materials across a range of temperatures above and below the 143°C (289°F) Tg.

Figure 3: Tensile strength vs. temperature comparison for Victrex PEEK carbon-filled injection molding polymers and aluminum.

Hybrid molding
With thousands of brackets on each commercial aircraft, removing weight and providing long-term strength with material solutions is attractive to those searching to improve fuel efficiency and reduce maintenance requirements. Components can range from clips and clamps to highly-loaded structural brackets. With loaded applications, the hybrid molding process can offer a step-change to current technologies.

Hybrid molding techniques enable the combination of optimized, complex injection-molded features with the mechanical strength of a continuously-reinforced thermoplastic composite. The reinforcement can either be carbon or glass fibers, depending on which properties are needed for the application. Unlike traditional overmolded metals or composites, the new process enables the use of a pre-formed composite shape. This can be inserted into a molding tool and then over-molded with an injection-molding grade.

Offer faster processing cycles by avoiding the use of autoclaves. It can also be recycled for use in other components. The largest challenge faced is that thermosets are the incumbent. With the demands on structural components expanding, implementing a thermoplastic PAEK-based system can be a viable solution given the range of performance benefits.

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Hybrid-molded composite bracket

Benefits of hybrid molded process structural brackets:
- 60% weight savings vs. metal
- Equivalent or better stiffness, strength, and fatigue
- Manufactured in minutes vs. hours for thermoset or metal solution
- Design flexibility integrates complex geometries and functions
- Lower energy processing
- Waste reduction
- Eliminates expensive metals and thermosets processing steps

Comparisons with PEEK

As the requirements on materials become more demanding, a frequent question is: “What is the maximum use temperature for Victrex’s polyether ether ketone (PEEK) materials?” Often, the assumption is made that the maximum use temperature is the glass transition temperature (Tg) of the polymer. In the case of amorphous polymers or thermoset materials, this would be the upper limit. When thermosets are exposed to temperatures above the Tg, mechanical performance drops dramatically and properties such as creep become significant and could lead to failure. In the case of semi-crystalline materials, however, properties are retained above the Tg (Figure 2). The change in properties is minimal when evaluating Victrex short fiber-reinforced materials at Tg compared to the unfilled materials.

The mechanical properties of the short fiber-filled Victrex PEEK materials also compare favorably with typical aerospace grades of aluminum above 100°C (212°F) (Figure 3). At more than 100°C (212°F), the properties of the aluminum start to fall dramatically to the point where the properties are similar to those of Victrex PEEK, particularly above the Tg of the polymer.

Summary

Material solution providers such as Victrex understand manufacturers’ needs to improve fuel efficiency and cost, which led to the development of a new PAEK-based polymer for composites and the hybrid molding technology. With these two advancements, engineers are able to design stronger, lighter, and lower-cost components than current metal and thermoset solutions. Given the achievable performance benefits, Victrex PAEK-based composites and hybrid molding are helping shape the future of flight.

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