In the world of composite fabrication, speed, precision, and customization have long been in tension with cost, tooling complexity, and production constraints. For years, composite fabricators have relied on traditional mold making and fixturing approaches that are often time-consuming, inflexible, and expensive, particularly in low-to-medium volume applications. But recent advancements in large-format additive manufacturing (AM) with aerospace-grade polymers have created new opportunities to bridge this gap, offering composite shops an agile new toolset for the production of layup molds, trim guides, cure tools, assembly jigs, and more. Central to this shift is the use of high-temperature polymer composites, including carbon fiber-reinforced thermoplastics like PEEK, PEKK, and PEI-class materials. These polymers offer the thermal stability, chemical resistance, and mechanical strength required for the demanding fabrication environments.

This isn't about replacing autoclaves with printers or eliminating experienced craftsmen from the shop floor. It's about supplementing traditional methods with flexible, scalable technologies that reduce lead times, support design iteration, and lower costs.

The Value Proposition: Faster Turnaround on Tooling

In composite manufacturing, lead time is often the most painful bottleneck, especially when custom tooling is needed. Traditional CNC-machined metal tools may require 8 to 20 weeks from design to delivery. Additive tooling, by contrast, can often be printed in days. This speed advantage has been repeatedly validated in practice. For example, aerospace firms have documented reductions of more than 80 percent in tooling lead time when switching from machined metal tools to high-performance printed polymers for composite layup forms.

In one recent example, a top-tier composite manufacturer needed a large mold for a prototype part. Traditional methods would have required 8 to 12 weeks. Instead, they utilized an additively manufactured mold using carbon-fiber reinforced PEI in under a week. After applying a thin epoxy coat, they proceeded directly to lay-up and vacuum curing. The result was a production-grade mold delivered on time, an outcome that would have been difficult to achieve using conventional methods.

Another compelling example comes from a project in aerospace composite development. Engineers needed a preform tool to shape a curved aircraft wing using a curing process that relied on electrical heating of the composite stack. Traditional tooling materials such as aluminum would conduct electricity along unintended paths and interfere with the uniform fabric heating. Epoxy-based tools lacked the thermal stability needed for the higher cure temperature—more than 150 °C.

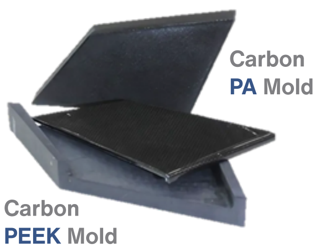
The solution was to turn to additive manufacturing. A high-performance thermoplastic tool was printed and finished into a reusable preform mold. The material's combination of electrical neutrality, temperature resistance, and mechanical strength made it a viable choice. With that tool, the team was able to reduce the heating stage time from an hour to ten minutes, thanks to direct electrical heating through the laminate. At the same time, lead time dropped drastically—from four weeks (typical CNC machining) to just sixty hours. The printed tool carried the composite through more than two dozen cycles without degradation, and total tooling cost was cut significantly.

Cutting Costs Without Sacrificing Quality

While high-performance AM materials are not cheap, the total cost of printed tooling often comes out lower than machined metal equivalents. The reasons include reduced labor, shorter production time, less material waste, and minimal rework. For small-batch or prototype production, the savings can be significant.

One automotive supplier used carbon-fiber polycarbonate to create an autoclave-capable mold. They were able to skip multiple weeks of lead time and reduce tool cost by more than 40 percent. These are not just theoretical savings. They have been realized on the shop floor.

Similarly, aerospace often grapples with the cost and lead-time associated with large, complex molds. One aerospace prime adopted an additive-based tooling using PEI to drive down the cost and time associated with traditional lay-up mold fabrication.



The company achieved a 75% reduction in tooling costs and shortened delivery from months to just weeks by replacing fiber-reinforced plastic molds with durable, autoclave-compatible AM tools. In addition to thermal stability at temperatures up to 250 °F (121 °C), the printed tools were drastically lighter, some weighing as little as 17 pounds, allowing for manual handling and reduced ergonomic risk.

Tools That Are Lighter and Smarter

Traditional composite tooling can be very heavy, bulky, and difficult to handle. Additive manufacturing makes it possible to produce molds and fixtures that are up to 80 percent lighter than their metal counterparts. This reduces handling time and improves safety.

The benefits go beyond weight. Designers can build in features like integrated vacuum paths, ribbing for stiffness, reference points for alignment, or internal sensors. These are features that would be difficult or impossible to include with traditional machining. They can lead to faster production, better part consistency, and fewer quality issues down the line.

Suitable Composite Processes for AM Tooling

Additive tooling has shown strong alignment with many processes, including:

- **Prepreg Layup with Oven Cure:** For parts cured up to 180°C, high-performance thermoplastics like PEI, PAEK, or fiber-reinforced PEKK are increasingly viable as mold substrates. Their thermal stability, combined with the rapid turnaround of printing, makes them ideal for short-run production or prototyping.
- **Out-of-Autoclave Processing (OOA):** Resin infusion, wet layup, and vacuum-assisted techniques typically operate at lower pressures and temperatures, placing less mechanical and thermal demand on tooling. These processes are particularly well-matched to additive tools, especially for large components where full-scale metal tools are cost prohibitive.
- **Trim and Drill Fixtures:** Additive manufacturing excels at building rapid and/or complex jigs and fixtures with integrated locating features, datum surfaces, and soft-touch inserts. Drill guides, trim supports, and bonding jigs can be quickly iterated and reprinted when design changes occur.

Other use cases include:

- Trim fixtures that conform to curved surfaces
- Bonding jigs with built-in reference geometry
- Drill templates used for first-article inspections or custom part validation
- Master patterns used to create composite tools through secondary processes
- Thermoforming tools to instill shape or alignment

1 Straight plastic pipe is prepared to be inserted into the pre-shaped mold.

2 Pipe is forced into the tooling.

3 The assembly is inserted into an oven reaching up to 190°C and cooled in water.

4 Since the pipe has been **thermoformed** to the new shape, it can be extracted from the mold.

Understanding the Limits

Not all composite fabrication applications are ideal for additive tooling. Full-pressure autoclave processes involving high-pressure resin transfer molding (HP-RTM) or compacted prepreg parts cured above 180°C generally demand metal tooling due to the thermal expansion mismatch, limited creep resistance, and potential for long-term dimensional drift in polymers. However, even in these cases, some printed materials have proven effective when paired with proper sealing and surface prep techniques.

For example, carbon-fiber reinforced PEI and PC materials have been used to produce tools that survive hundreds of autoclave cycles without degradation. These tools require care in design and post-processing, but they are not limited to low-performance or low-temperature tasks.

Surface finish and dimensional stability are also key considerations. While AM can produce parts with excellent accuracy, some applications require post-processing (machining or coating) to meet stringent tolerances or cosmetic requirements. This is especially true for aerospace components with tight ply-edge control or optical assemblies requiring smooth tool surfaces.

In general, if the tool must survive high pressure, high temperature, and dozens of reuse cycles without degradation, metal remains the gold standard. But for lower temperature applications, short-run tooling, or complex shapes, printed, high performance polymers are increasingly competing.

Design Freedom and Embedded Functionality

Perhaps the most underappreciated advantage of AM in composite tooling is design freedom. Additive techniques allow designers to embed functionality into the mold itself such as integrated vacuum channels, conformal cooling lines, or built-in locating pins. In one published example, a custom AM layup mold for a fuselage included vacuum ports and tape lines printed directly into the tool body, simplifying bagging setup and improving vacuum integrity during cure.

This kind of embedded functionality is nearly impossible with subtractive tooling, where holes, grooves, and inserts must be added post-process. AM also supports topology optimization, enabling lattice-reinforced tools that maintain stiffness while reducing print time and material use.

CRG Defense: Bridging Design and Production

CRG Defense has emerged as a leader in this evolving space, leveraging its hybrid capabilities in design, polymer chemistry, and advanced additive manufacturing to deliver tooling solutions that meet real-world composite fabrication needs.

With in-house thermoplastic compounding and formulation labs, CRG Defense can develop or modify materials tailored to specific tooling needs. That means material solutions with increased thermal stability, improved chemical resistance, or tailored coefficient of thermal expansion to better match composite part behavior.

CRG Defense's design team uses tools like SolidWorks and CATIA, supported by finite element analysis (FEA) and computational fluid dynamics (CFD) simulations, to ensure mold structures are both printable and functional under load. Their additive manufacturing systems support a wide range of engineering polymers, including high-temperature and carbon-fiber-reinforced grades, with build volumes exceeding one cubic meter enabling production of tools, jigs, and fixtures for even large-format composite parts.

Their integrated capability set also includes 3D scanning for reverse engineering, post-processing via 5-axis CNC, and characterization tools such as TGA, DMA, and thermal conductivity testing to validate material performance under process conditions.

What sets CRG Defense apart is the ability to go from concept to printed, usable tooling in days not months, with a quality assurance system compliant with AS9100 and ISO 9001 standards, ensuring consistency and traceability.

A Thoughtful Path Forward

The additive tooling revolution in composites isn't about hype. It's about smart engineering and practical benefits. By combining speed, design flexibility, and material performance, large-format AM has carved out a valuable niche in the composite workflow. For shops that need to move fast, prototype affordably, or think innovatively, AM may be the tool they've been waiting for.

To learn more about how additive tooling can support your composite fabrication needs, or to explore potential solutions tailored to your environment, **please contact CRG Defense at sales@crgdefense.com.**