

Reduce Costs and Develop More Accurate Tooling with Polyurethane Foam

A technical paper by General Plastics Manufacturing Company



INTRODUCTION

In manufacturing, tooling is the process of designing and engineering the tools necessary to produce the parts or components needed to develop the final product. It can include work-holding tools such as jigs or fixtures; cutting tools such as milling and grinding machines; dies, molds, and patterns for sheet metals and plastics; and welding and inspection fixtures. There are an infinite number of methods for tool development and numerous materials, ranging from composites to hard metals that can be used to make these tools.

Tooling is a keystone technology used in almost every major market – from transportation to electronics to food processing – and is often a routine part of the design and production process. With so many other factors to consider, it's easy to fall back on the default tooling methods of old. But for many organizations, moving to an alternate tooling material or using a new process for designing and developing tooling, could help you more efficiently deliver that bullet-proof design, saving both time and money.

Across industries, more and more manufacturers are moving to composite, or “soft” tooling methods with materials such as polyurethane foam. While this may not be the right choice for all applications and tooling needs, there are numerous instances where using polyurethane foam either as the final tool or to aid in developing the final hard tool can help you reduce costs, iterate faster, or produce a more accurate tool.

This whitepaper examines the key considerations to evaluate your tooling needs and how to best take advantage of tooling strategies and techniques using polyurethane foam.



High Cost of Small Mistakes

Tooling is a critical part of the manufacturing process. Using poor quality tooling will likely result in inferior components being constructed that are prone to malfunction, fail under stress, or unable to meet project requirements or specifications. This can result in a large volume of parts being wasted or even require you to begin production all over again.

The quality of the finished part, its properties, the speed and accuracy with which the part can be produced, and repeatability in high-volume runs all depend on the precision and characteristics of your tooling. Using the correct process and right material to create those tools is critical to ensure properly functioning parts. In short, to create the best product, you must design the best tools, engineered to the highest quality, for the job.

Top Considerations for Designing the Right Tooling

There are many considerations when selecting the right tooling for your application, but here are a few of the most essential questions to ask yourself:

- How will the tool be used and what performance requirements are required for that use?
- What material best meets those requirements?
- What are the dimensions of the finished tool?
- What is your production rate?
- What are the curing conditions?
- What are your tolerance levels?
- How many times does the tool need to perform its operation?
- What contours and integrated functions does the product have?
- What is the required surface finish?
- What is the time frame from prototyping to production?
- What is your budget?

Selecting the appropriate method ultimately depends on how you are using the tool and achieving a perfect (or near perfect) match of coefficient of thermal expansion (CTE), dimensional complexity, production rate and curing conditions, tolerance levels and surface finish, among others. The answers to these questions will guide you to the correct process for finding this match and engineering the right tooling that will lead to the production of high-quality, properly functioning parts.

Tooling Techniques: Hard Tooling vs. Soft Tooling

There are two general types of tooling—hard tooling and soft tooling. Hard tooling involves using metallic materials such as steel, aluminum, or metal alloys like Invar; while soft tooling materials are typically composite materials such as fiberglass, high-density foam, machinable epoxy boards, or wood/plaster models.



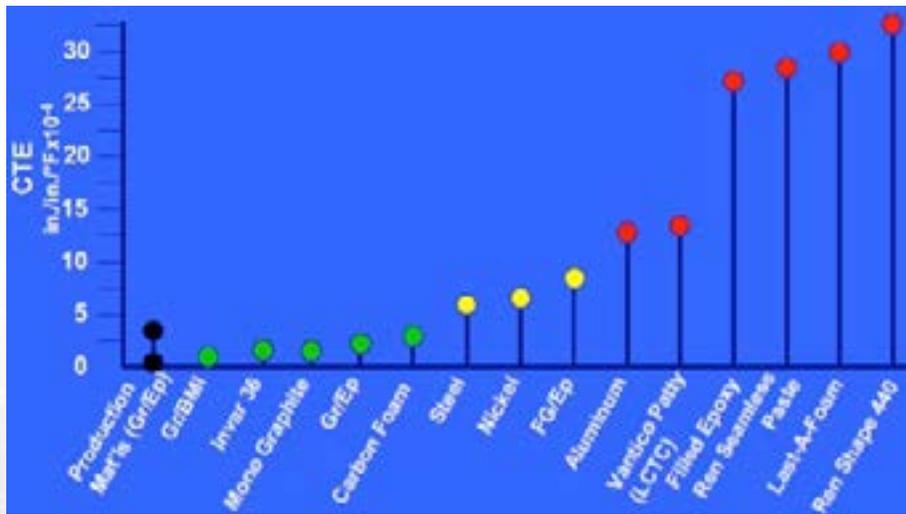
High density tooling foam



Graphite Hexcel Corporation HexTool®

Historically, hard tooling has been the go-to standard in the manufacturing industry. It's durable, produces good surface finish, and stands up to a lot of pulls for high-production runs (e.g., up to 1,500 autoclave cycles for steel tools). Plus, metals generally have low CTEs, which works well when producing components that also have a low CTE, require repeated high-temperature cycling, or demanding tolerances.

The CTE measures the fractional change in size per degree change in temperature at a constant pressure. By matching the CTE values of the tooling and production materials, the materials will expand and contract at the same rates when exposed to varying curing temperatures – resulting in high-quality parts with precise dimensional tolerances. Just as you should select a hard tooling method when producing components with low CTE, soft tooling options are often a better choice when manufacturing composite parts to reduce CTE mismatch and maintain dimensional accuracy during a cure. The CTEs of common tooling materials are shown below.



Relative CTEs of Common Tool Materials (Source: SME.org)

Compared to hard tooling, soft tooling is easier and faster to machine into complex shapes and can quickly be reworked or modified as needed. The soft tooling raw material, as well as the process of machining it, also comes with a lower price tag, and is easier to maneuver with its lighter weight.

These benefits are why more and more manufacturers are moving to lighter-weight soft tooling for prototyping and other time-sensitive projects, creating tools with large or complex designs, production runs with low-part volumes, or when low-cost solutions are required.

Polyurethane Foam: A Versatile Choice Among Soft Tooling Options

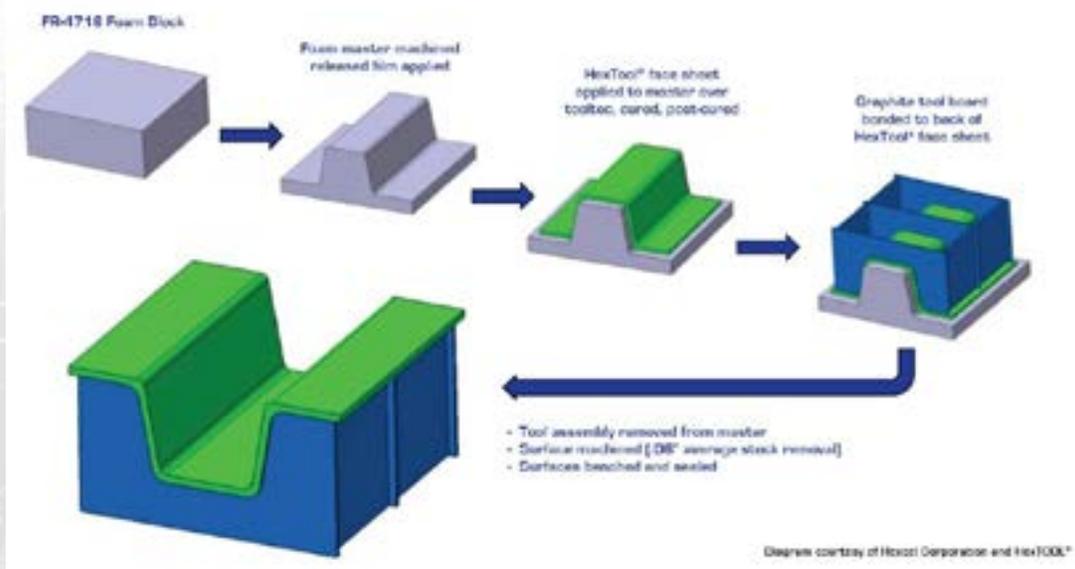
While a variety of materials can be used for soft tooling, polyurethane foam tooling boards (also known as high-density urethane or HDU), such as General Plastics LAST-A-FOAM®, is a versatile option. LAST-A-FOAM® tooling boards are a preferred alternative for large-sized tools where material, processing, handling, and shipping costs of metal are an issue, or in limited-run tooling where metal tools are cost prohibitive. These tooling boards are also ideal as master models and composite tooling in applications ranging from low-temperature layups to high-temperature autoclaves.

Plus, with projects that require tight turnaround times, foam tooling can significantly shorten your R&D cycles and get your product to market faster. Let's look at three applications where LAST-A-FOAM® polyurethane foam is the ideal option.

Foam Master Molds

It is often a challenge to develop tooling that can meet tight tolerances yet withstand high temperatures and repeated curing cycles. While the ability to easily manipulate and shape polyurethane foam makes it a great fit for creating a tool with tight tolerances or unique shapes, it will not withstand high temperatures or repeated curing cycles like a metallic or composite tool can. Nevertheless, LAST-A-FOAM® high-temperature tooling boards have proven their value as a master mold due to its ability to withstand high-heat prepreg and autoclave curing. It serves as an excellent substrate because of its high glass transition temperature (T_g), high compressive modulus, and predictable CTE.

These tooling boards are low cost and can be machined to a tight tolerance and into complex shapes. If changes are needed on the master tool, the material can be easily modified and reused at a fraction of the cost of metal tooling. An example of the steps to create a master mold using LAST-A-FOAM® is shown below.



An example of using LAST-A-FOAM® as a master mold to create a composite HexTool®.

Prototyping

Companies typically go through several iterations when developing new parts to ensure they perform as intended. Thus, it is crucial to choose tooling materials that are cost effective and easy to modify, allowing for various design modifications while meeting project timelines and budgets.

LAST-A-FOAM® is a cost-effective material that is not only extremely stable and precise, but it also offers the flexibility to cut and re-cut as you make product iterations. For example, in experimental or new programs in the aerospace industry where there are typically several design iterations upfront, using LAST-A-FOAM® is most beneficial because you can iterate prototypes quickly and inexpensively. It also has applications in the transportation industry, with nearly every major automotive company using LAST-A-FOAM® for their prototyping work.

While choosing a less expensive and less permanent material is an option, it should not be the only consideration. Staying away from materials that may soften or deform in applications where the material's temperature stability at a high temperature is key. This will create wide variances in tolerance and produce parts with unpredictable dimensions.



Students at the University of Utah used LAST-A-FOAM® to build a mold for the carbon fiber outer shell of their formula SAE racecar.

Surface Verification Tool

Another soft tooling application is to use the polyurethane foam as a surface verification tool. Before beginning the time-consuming process of machining hard tooling and cutting an expensive piece of metal, it's best to use a less expensive surface verification tool to ensure your tool path is accurate. The ability to easily machine and cut LAST-A-FOAM® makes it a great fit for surface verification.

Layup Molds and Mandrels

For creating layup molds and mandrels, the LAST-A-FOAM® tooling board series is a great option because of the foam's dimensional stability and cell structure and the ability to easily machine it. Since most layup mold and mandrel applications have tight tolerances, ambient or low temperature cures, and a low number of pulls, LAST-A-FOAM® is an effective material for these applications.

For example, major marine manufacturers use LAST-A-FOAM® because it bonds easily and securely to fiberglass laminating resin systems. The tough, grain-free tooling board has an excellent bonding ability that allows manufacturers to create the oversized blocks needed for molds for large hulls.

Additionally, wind turbine and aircraft manufacturers use LAST-A-FOAM® when developing tools to create spars that run the length of the wing of an airplane or wind turbine to prevent it from buckling under stress. LAST-A-FOAM® is ideal for construction of these spars because of it allows you to easily accommodate their complex hollow tube shape.

To make the spars, a polyurethane foam mold is created, then the carbon fiber is laid up on the tool and cured. Next, the foam is extracted, which reveals the layup tool that is used for creating the spars. A resin is then added, the tool is vacuum bagged, and then it is cured, usually at room temperature, before being demolded and the finished part is extracted.

Case Study: How Tooling Using LAST-A-FOAM® Helped Accelerate Aerospace R&D Cycles

[BLR Aerospace](#) specializes in creating aerodynamic performance enhancements and exterior modifications for helicopters and turbine-powered aircraft. To quickly and profitably develop new aerodynamic cowlings, the company required a stable, easily machined tooling material for prototyping composite parts – specifically large-scale, life-sized carbon fiber and fiberglass parts. Previously, the company used metallic tools, which were time-consuming and expensive to produce. Their design engineers sought an affordable alternative to more permanent tooling to allow for various design iterations, while factoring cost and time requirements.



An example of a BLR aircraft in flight.

After trying out other tooling materials, BLR zeroed in on General Plastics' [LAST-A-FOAM® FR-4700 High-Temperature Tooling series](#) because of its temperature stability, uniformity, and excellent machinability. According to lead project engineer Russell Bezzo, "Machining tools using this foam allows us to lay up the carbon-fiber and composite parts, put them in the oven and make true-to-life prototypes using the actual materials that we'll use in production." Moreover, the lower-weight tools were less cumbersome to handle when making prototypes and cost less to ship to their composite manufacturing facilities.

BLR Aerospace also took advantage of General Plastics' expertise and [CNC machining capabilities](#) to make its prototype tools, which simplified the tooling process and expedited the timeline. Overall, relying on General Plastics for both its high-temperature tooling foam and CNC machining capabilities allowed BLR to achieve tighter tolerances, faster design iterations, shorter R&D cycles, and greater cost efficiencies.

Benefits of LAST-A-FOAM®

Your choice of tooling material can impact product quality, design and production costs, and on-time project completion. If you're looking for a cost-effective and fast time-to-market option for your limited run tooling, LAST-A-FOAM® may be the right choice for you. LAST-A-FOAM® comes in a number of densities that withstand a wide range of temperatures up to 400°F.

It is easily machined into complex shapes with fine details, and can be modified by simply bonding on additional foam with adhesive, filling voids, or carving off any excess. Lead times are generally shorter since the machining process is faster and the material is readily available. In addition, LAST-A-FOAM® is lightweight and much easier to handle, especially for large parts that need to be maneuvered around a factory floor.

Its high Tg and low CTE make it suitable for use in vacuum-forming applications, whereas other urethane products may soften or deform. It has an excellent bonding ability to create monolithic tools and molds for large-scale projects and is non-abrasive, uniform from sheet to sheet, and grain-free to support fine surface finishes with virtually any coating system.

Based on its material properties, low weight, and ease of accommodating complex shapes, LAST-A-FOAM® could serve as a viable alternative to traditional metallic tools, saving you time and money on your next tooling project.

To find out if composite tooling suits your project requirements, read our [LAST-A-FOAM® Tooling & Molds User Guide](#) or [contact us for a free consultation](#) to guide you through the tooling decision process.

