Tooling options

This document is being made available for historical reference only. For this reason, it has not been updated with new tooling options. Many of the following processes and tooling options are no longer in active development, and some have been abandoned completely.

Indirect tooling options

Indirect tooling is the method of making tools by first producing patterns, which are then used to create mold components. A number of indirect options are available for prototype and short-run production tooling. Several have been developed and commercialized, but have experienced little success in the marketplace. One exception is silicone rubber tooling, which is very popular and continues to be used extensively for the casting of urethane parts. Epoxy-based composite tooling has also experienced some success, but nothing like silicone rubber tooling.

Silicone rubber tooling

One of the most popular tooling applications for additive manufacturing (AM) is the production of room temperature vulcanizing (RTV) silicone rubber tooling. The purpose of RTV tools is to create urethane or epoxy prototypes, often under vacuum (hence the term vacuum casting). The process of making a rubber mold consists of making a master pattern, usually on an AM machine, finishing the pattern to the desired appearance, casting RTV silicone rubber around the pattern to form the mold, and then injecting the mold with two-part thermoset materials to create molded plastic parts. Although urethane and epoxy materials are typically not used for high-volume manufacturing, they are available with a range of material properties, many of which simulate the thermoplastic materials used in production.

Silicone rubber tooling provides fast, inexpensive molds, excellent part cosmetics, and the option of using multiple materials. The process is suitable for small or medium-sized parts. Another benefit of silicone rubber tooling is the negative draft (undercuts) that can be achieved due to the flexibility of the mold material. The primary weakness of the process is that the properties of the urethane materials are different from those of the thermoplastic materials used in production. Tool life limitations also restrict production numbers to a relatively small quantity of typically less than 50 parts per tool. Due to material cost and labor demands, individual part prices are relatively high.

Consider silicone rubber tooling and vacuum casting when the material properties of the prototypes can differ somewhat from thermoplastic parts, when lead times are critical, part geometry is complex (including negative draft), and required quantities are relatively small.

Epoxy-based composite tooling

Like silicone rubber tooling, epoxy-based composite tooling requires a master pattern. Typically, this pattern is created using an AM process. The pattern is finished and then embedded in a parting line block to create the parting line of the mold. Metal inserts are placed in areas where the epoxy is unlikely to withstand the pressures of the injection-molding process. Epoxy is then cast against the pattern and parting line block combination to create the first side of the tool. Once the epoxy has cured, the assembly is inverted, and the parting line is removed, leaving the pattern embedded in the first side of the tool. The second side of the tool is then cast against the first. Tools are frequently created as inserts to be mounted in a mold base.

The following sequence highlights the key steps in the procedure for producing aluminum-filled epoxy tools. The creation of the run-off (also called the parting block) is similar to other pattern-based tooling processes, such as spray metal tooling.

1. Produce the master pattern, usually with an AM process.
2. Identify the parting line.
3. Produce a nesting fixture to hold the pattern in place. The nesting fixture, which is usually made of wood, must be substantial enough to hold the pattern securely.
4. Cut and attach pieces of wood to follow the parting line. Depending on the complexity of the parting line, this might require 10 to 15 pieces.
5. Use wax to fill the gaps and cracks between the pattern and the pieces of wood.
6. After the run-off is complete, apply mold release to the pattern and run-off.

Note: Just prior to prepping and casting the first half, copper water lines should be in place. Depending on the part and the side of the tool being cast, sprue bushings and ejector pins (sleeves) must be in place. Also, the steel frame that contains the mass cast must be constructed prior to casting. The frame provides strength to hold the tool together to prevent cracking.

7. Apply surface coats of epoxy to the pattern and run-off.
8. Fill with 35% epoxy and 65% aluminum composite material to complete the first side of the mold.

Note: Timing is critical between Steps 7 and 8. If the composite material is poured prematurely, the aluminum chips (1–3 mm in size) will penetrate the surface coats of epoxy. If too much time expires, the surface coats will not adhere well to the composite material.

9. Remove the pattern and run-off. The first side of the mold is complete.
10. Position the pattern back into the finished side of the mold.
11. Produce the opposite side of the mold. There is no need to produce a run-off, because the completed side of the mold serves this purpose.

Composite tooling permits the use of production thermoplastic materials, and it works best with parts of low-to-medium complexity. This tooling approach can create large parts with molds that are relatively inexpensive when compared to conventional machined tooling. On the down side, this approach offers limited mold life and long cycle times when molding parts. Also, complex geometries may require many metal inserts, increasing cost and lead time.

Spray metal tooling

Spray metal tooling is constructed very much like epoxy-based composite tooling, except that a thin layer of metal is deposited using a spray process to create the surface of the mold. The metal is often kirksite, a zinc-based alloy, although other metals can be sprayed successfully, including steel. The metal surface is usually backed with epoxy or a low-melt alloy. Proper selection of the backfill material can improve the cooling rate of the tool.

Spray metal tooling is good for large parts. The mold-making process introduces little or no additional shrink, so the process is relatively accurate. Because the mold has a metal surface, injection cycle times are better than those of epoxy-based composite tooling. The disadvantages are that the mold has a limited life, and complex shapes and features may require adding metal inserts, increasing cost and production time. Spray metal tooling is a candidate for applications with parts of significant size and low-to-medium complexity.

A unique form of spray metal tooling currently under development is Cold Gas Dynamic Manufacturing (CGDM). Researchers at the University of Liverpool’s Department of Engineering are developing the technology. CGDM is a high-rate, direct deposition process capable of combining many dissimilar materials in the production of a single component. The process is based on Cold Gas Dynamic Spraying (CGDS)—a surface coating technology in which small, unheated particles are accelerated to high velocities, typically above 500 meters per second (1,640 feet per second), in a supersonic gas jet and directed towards a substrate material.

The process does not use a heat source, as with plasma and High Velocity Oxy-Fuel (HVOF) spray technologies, but instead exploits the high kinetic energy of the particles to effect bonding through plastic deformation upon impact with the substrate or previously deposited layer. As a consequence, it lends itself to the processing of temperature-sensitive material systems such as oxidizing, phase-sensitive, or nanostructured materials. To achieve metallic bonding, incident particles require velocities greater than a certain material-specific threshold value, such that thin surface films are ruptured, generating a direct interface. This bonding mechanism has been compared to explosive welding.

The cold spray process is similar to CGDM. The technology came to the U.S. in 1994, 10 years after Russian inventors discovered its potential. Sandia National Laboratories (Albuquerque, New Mexico) developed the process further while leading a consortium that included Alcoa, Ford Motor Company, Pratt & Whitney, DaimlerChrysler, and Siemens/Westinghouse. Australia’s Commonwealth Scientific and Industrial Research Organization (CSIRO) is actively developing the cold spray technology.

RSP Tooling

Originally developed by the Idaho National Engineering and Environmental Laboratory (INEEL), RSP Tooling has been working toward the commercialization of a process called Rapid Solidification Process (RSP) Tooling for many years. Belcan Corp. has invested in the company and partnered with it to manufacture the machines.

The process starts with a pattern of the tool being generated from a CAD solid model. Though SL and other additive techniques can be used, CNC cutting of wax is the primary means of pattern generation due to accuracy and reusability of raw material. A ceramic reversal is poured and created from this pattern. From a crucible, molten metal is fed to a nozzle and atomized by contact with a high velocity gas jet. A 5-axis manual gripper holds the ceramic pattern as a spray system deposits the metal from a fixed nozzle onto the ceramic to form the tool.

It is possible to spray many tooling alloys, including tool steels such as P20, H13, and D2. Minute details such as the ridges of a fingerprint can be replicated. The company has added Inconel 718 and 738 for its toughness and high-temperature capabilities. In general, the RSP Tooling process provides a means to control carbide formation and growth in tool steels. This allows molds and dies to be heat treated by artificial aging. Sprayed H13 has a hardness of 56 Rockwell C, while age hardening can increase the hardness to 62 Rockwell C.

The machine can handle parts up to 27 kg (60 lbs) that measure 230 x 230 x 100 mm (9 x 9 x 4 inches). Features with aspect ratios greater than 2:1 and deep holes and slots can be problematic. RSP Tooling is selling tool inserts primarily in the forging and die-casting markets. RSP Tooling plans to eventually introduce a commercially available machine that is capable of producing a diameter of approximately 100 cm (39.4 inches).

Cast kirksite tooling

Kirksite is a zinc-aluminum alloy with excellent wear resistance. Although kirksite has been cast for decades, it regained some popularity with the growth of additive manufacturing. Due to other competing rapid tooling processes that have emerged in recent years, cast kirksite has again lost some of its appeal. However, for some applications, the process can still yield cost-effective results. DaimlerChrysler has used the process.

The process for making cast kirksite tooling begins much like the process for epoxy-based composite tooling, except that two additional reversals are required for creating tooling in a more durable material. First, a shrink-compensated master pattern of the part is produced, typically using an AM process. A rubber or urethane material is then cast against the part master to create patterns for the core and cavity set, which will be cast in kirksite. Plaster is then cast against the core and cavity patterns to create molds into which the kirksite is cast. Once the kirksite is cast into the plaster molds, the plaster is broken away, and the kirksite core and cavity are fit into a mold base.

For years, Armstrong Mold Corp. (East Syracuse, New York) has used a prototype injection-molding process that employs cast kirksite cavities. The company is using the process to produce thermoplastic parts in two to three weeks. According to Armstrong, tool life is dependent on many factors, particularly the material used. Typical runs are 50–1,000 pieces, although some kirksite molds have produced up to 200,000 pieces.

Complex shapes can be molded with kirksite tooling. Also, it offers a more durable mold than epoxy or spray metal tooling. Its disadvantage is that the mold is not as accurate as an epoxy or spray-metal mold because of the reversals and the material shrink in the metal-casting process. To accommodate for this loss of accuracy, surfaces can be machined to tolerance. Cast kirksite tooling would be typically chosen for medium-sized production quantities of larger parts without tight dimensional requirements.

3D Keltool

3D Keltool is a powder metal process used to make injection-mold inserts and other durable tooling from master patterns. Keltool was originally developed by 3M in 1976 and was sold and further developed by Keltool Inc. In 1996, 3D Systems purchased the technology from Keltool Inc. and renamed it 3D Keltool. 3D Systems continued to develop and improve the process. It is proprietary, so many of the details of 3D Keltool are not publicly known.

After 3D Systems acquired DTM in 2001, it began to favor SLS tooling at the expense of 3D Keltool. Consequently, activity associated with 3D Keltool was very quiet from 2001 to 2003 and has been non-existent since then. 3D Systems has licensed the process to several companies. In March 2003, the sole licensee of 3D Keltool in the U.S. was General Pattern Co. (Minneapolis, Minnesota). It acquired the license from Rapid Tooling Technologies, LLC (St. Paul, Minnesota). General Pattern continues to practice the 3D Keltool process, but at a reduced level. The company targets the applications that are a natural fit. “It is best to apply it to tooling inserts that are smaller than 75 x 75 x 73 mm (3 x 3 x 3 inches). Master preparation is also a key to success,” said Brad Fox of General Pattern. Other licensees remain active at some level, although 3D Systems makes little mention of the technology on its website.

The 3D Keltool process typically starts with a CAD design of core and cavity inserts, followed by the creation of core and cavity patterns with stereolithography or some other AM process. Once these core and cavity patterns have been finished to the desired surface, silicone rubber is cast against them to create molds into which a mixture of metal powder and binder is poured, packed, and cured. The metal mixture consists of finely powdered A6 tool steel and even finer particles of tungsten carbide. At this point, the cast core and cavity inserts exist in a *green* state. These green inserts are fired in a hydrogen-reduction furnace to burn away the binder, sinter the metal particles, and infiltrate copper into the inserts. This produces solid metal inserts that are approximately 70% steel and 30% copper, with physical properties similar to that of P20 tool steel. The inserts are finish machined, drilled for ejector pins, and fitted into mold bases.

MetalCopy

MetalCopy, formerly known as WibaTool, is a powder-based process jointly developed by IVF Industrial Research and Development Corp. and Prototal, both of Sweden. The process is similar to 3D Keltool. However, it uses a binder that is said to be less viscous, making it suitable for small features such as narrow, deep slots. Also, the metal mixture is something other than A6 steel and does not include tungsten carbide.

MetalCopy uses a copper alloy rather than pure copper for infiltration. MetalCopy has a lower sintering temperature and is, therefore, believed to encounter less process shrinkage. Due to insufficient market demand, Prototal discontinued MetalCopy in mid-2005.

Ford Sprayform

In 1999, Ford (Dearborn, Michigan) acquired the Sprayform process from Sprayform Holdings Ltd. of the UK. It uses twin wire metal arc guns to spray carbon steel onto the surface of a pattern. Prior to 1999, Ford had licensed the Sprayform technology, expecting to use it for prototype tooling, but found that it could also be used for production tooling. Some issues remain, such as repairing Sprayform tools, yet Ford has used Sprayform tools to produce more than one million stamped articles.

The process involves spraying steel onto a ceramic pattern from a robotically controlled wire spray gun. In producing the patterns, Sprayform uses a special freeze-casting process that ensures stability and accuracy of the ceramic. The sprayed metal is referred to as the shell. For stamping tools, the shell is typically 19 mm (0.75 inch) thick. An epoxy fill is applied to the backside of the shell and then the composite structure is removed from the ceramic pattern. The original model used to form the ceramic pattern may be reused for other tools, but the pattern is destroyed when removing the metal. The work cell currently operating at Ford can accommodate parts up to 760 x 1015 x 250 mm (30 x 40 x 10 inches).

Sprayform is being used to make dies that are capable of producing 300–400 prototype sheet metal stampings. The process is being used only for Class B structural parts that are hidden from view. The company is interested in scaling up the process to see how far it can go beyond prototyping, according to Allen Roche of Ford. “Several benchmark production tools for stampings have been created over the past year,” Roche stated. “One tool reached 70,000 parts, another over 200,000, and one that yielded more than 1 million parts.” The benchmarking has helped Ford understand the best applications for the process in the future, Roche explained.

Rapid Moulding Technologies

Rapid Moulding Technologies Ltd. (RMT) of Cambridgeshire in the UK owns a process previously known as Swiftool. It uses proprietary composite materials that are pressed against a pattern to produce complete molds and tooling inserts. The company offers two types of mold materials: one for molding thermoplastics and thermoset resins and another for a soluble core material.

The company’s smallest system, named S10, offers a capacity of up to 150 x 150 x 150 mm (6 x 6 x 6 inches) and produces molds using a 10-ton press within a vacuum. The system includes a vacuum chamber with a 23-

liter mixer, training, and a starter pack of materials. RMT also offers the S50 system, which produces molds using 50 tons of pressure (with vacuum assist), and a pressing area capacity of 350 x 300 mm (14 x 12 inches). The largest system, S200, produces molds using 200 tons of pressure (with vacuum assist) and a pressing area capacity of 700 x 600 mm (28 x 24 inches). The mold material consists of 30% polymer and 70% fibers.

Organizations that have purchased systems include Procter & Gamble (UK), Federal Mogul, and the Institute of St. Gallen in Switzerland. RMT has also offered the technology as a service, but reported in early 2006 that they rarely use it themselves due to the company's success with high-speed CNC machining.

PHAST

Prototype Hard And Soft Tooling (PHAST) is a pattern-based rapid tooling process used to create intricately detailed, multi-cavity, injection-mold tooling. The PHAST process uses AM patterns, handcrafted patterns, or objects. The process is currently owned by Milwaukee School of Engineering (MSOE). It was donated to the university by Proctor & Gamble in 1999. After the donation, MSOE developed many aspects of the technology.

The basic PHAST process starts with a pattern that represents a positive form of the part to be molded. This pattern is used to produce a mold master in a soft, accurate, and reusable material. From the master, ceramic molds are produced and used to cast wear-resistant Metal Matrix Composite (MMC) mold inserts. The non-magnetic MMC material consists of 30% tungsten (by volume) and 70% bronze. A highly thermally conductive MMC is also available, providing the potential for reduced molding cycle time, as well as EDM electrode materials.

PHAST can be used for production injection-mold tooling, as well as prototype and bridge tooling. PHAST can be processed in as little as a week, according to MSOE. This fast turnaround can be attributed in part to the streamlined machining and mold-base setup methodology developed at the university. PHAST is best for open-shut mold geometry and where complex parting surfaces are not an issue. The ideal mold insert size is smaller than 100 x 100 mm (4 x 4 inches) and 64 mm (2.5 inches) deep. The process is not as accurate as CNC machining, at ± 0.09 mm per 25 mm (0.0035 inch per inch), but it can reproduce features smaller than is capable with CNC machining.

EDM-rich mold geometry, with high feature density, is where PHAST excels. With the quality of AM patterns produced today, the pattern preparation effort is minimized and the accuracy is acceptable for many applications. This, combined with a process that can produce one cavity every four hours (using one mold master), regardless of complexity, makes PHAST an excellent high cavitation solution. The need for high-end AM equipment is avoided and patterns are readily available with no capital equipment investment.

PHAST has several unique characteristics, specifically high resolution and high aspect ratios, which are leading to interesting new applications. The ability to capture features smaller than 0.02 mm (0.0008 inch), much smaller than fingerprints or LP record grooves, provides opportunities not economically available from conventional mold-making approaches. Also, the ability to capture the surface detail of objects, such as leaves or other natural or manmade textures on flat or complex surfaces, is an interesting feature of the PHAST process.

Direct tooling options

Direct tooling is the direct manufacture of tooling, rather than the creation of a master to assist in the making of a tool. With the exception of SL tooling, the following methods do not use an AM system for the production of the parts that go into the tool. Instead, alternatives to AM processes were used to explore and develop "rapid tooling" technologies to compete with traditional, machined tooling.

SL tooling

by Russ Harris

SL tooling refers to mold cavities that are produced by a stereolithography technique and subsequently directly used in a molding process, such as plastic injection molding. The Direct AIM process from 3D Systems was one of the first SL tooling methods. AIM stands for ACES Injection Molding, and ACES stands for Accurate Clear Epoxy Solid.

SL tooling is capable of producing low volumes of plastic injection-molded parts prior to commitment to hard tooling. The parts are similar to, but not exactly like, those created with traditional metal tooling. Although there are examples of continued activities with SL tooling in some educational institutions, there are currently few industrial applications. This may be due to the advancements made in alternative methods, particularly high-speed machining techniques for metal mold production.

The key to successful SL tooling is to understand the demands of its mold design and injection mold parameters, which are very different from those for metal molds. A drawback of the SL tooling process is that the tools are susceptible to failure after producing only a small number of parts. Previous research by the Rapid Manufacturing Research Group at Loughborough University in the UK has shown that mold wear is mainly dependent on the polymer used. However, it has been demonstrated that appropriate choices in mold design and process variables can reduce the risk of failure. Previously, the use of proper settings has allowed the successful molding of parts as large as 165 x 400 x 48 mm (6.5 x 16 x 2 inches) and geometrically complex in an aggressive molding polymer such as PA66 with 30% glass content.

Since its introduction, the advantages of SL tooling were promoted as providing a quicker and less expensive alternative to traditional machined metal tools, when low volumes of molded parts are required. However, since the introduction of SL tooling, the speed of machined tooling has improved vastly, and its cost has dropped to the extent that most advantages of SL tooling have been nullified. The future use of SL tooling may now lie in the exploitation of its characteristics that allow virtually any shape to be produced.

The thermal properties of stereolithography materials, notably low thermal conductivity, have often been stated as a vulnerability of this process. However, it can actually help to enable the molding process by allowing for the slower speeds and pressures required for the lower strength epoxy mold. In fact, the SL tooling process has shown itself to be capable of producing parts that would not be possible under the same conditions using a metal mold. The thermal characteristic of SL tooling has made it possible to mold fully crystalline PEEK, which has an injection temperature of 400°C (752°F). An equivalent steel mold would require a pre-molding temperature of about 200°C (392°F).

Also consider that the thermal characteristics of SL molds have an influence on the morphological structure of the parts. In some polymers, this may lead to a difference in the morphology of parts from SL tools as compared to those from metal tools. Such morphological differences can affect the shrink and mechanical properties of the molded part. When using SL tooling, one must decide if these differences are critical to the function of the part.

Some work has shown that the slower molded part cooling imposed by SL tooling provides an opportunity to make some variations in the molding parameters in crystalline polymers. This allows the control of critical morphological factors, including the level of crystallinity. The subsequent level of crystallinity dictates many resultant part properties. The process modifications in this work were realized without changes to the machine, tool, or molded material (i.e., external cooling control, different polymer, etc). This demonstrates the possible "tailoring" of molded part properties that would allow certain desirable part properties. These revelations demonstrate an advantage of SL tooling that was not possible with metal tooling.

Laminate tooling

by Candice Majewski

The laminate tooling process combines the traditional benefits of AM technologies (lower costs, shorter lead times, and the option of including conformal-cooling or conformal-heating channels), with the ability to produce molds that are much larger than those produced by other AM technologies.

Daniel Walczyk of Rensselaer Polytechnic Institute (Troy, New York) worked on Profiled Edge Lamination (PEL) tooling as part of a five-year project. Further work was planned to examine the use of variable laminate thicknesses, as well as cost and time predictors and different bonding methods.

Thomas Himmer of the Fraunhofer Institute for Material and Beam Technology (Dresden, Germany), worked on laminate tooling, particularly looking at new applications for the automotive and aircraft industries. The process involved the laser cutting of laminates that are joined together before being CNC machined to provide an improved surface finish. A laser/plasma hybrid spraying technique was shown to be effective for depositing coatings for surface protection.

Loughborough University investigated the use of laminate tooling for the molding of polyurethane foam. Research to control tool temperatures more accurately using conformal-heating channels was conducted, with the aim of improving the flow properties of the foam to allow thinner mold sections. The researchers investigated whether better temperature control would allow the foam to expand further and into thinner sections.

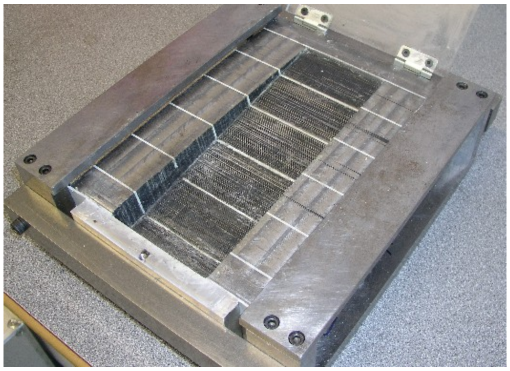

Photo of laminate tool used to evaluate the effect of tool temperature on foam flow properties for polyurethane foam molding, courtesy of Loughborough University

Warwick Manufacturing Group completed a three-year study of the use of laminated tooling. Results showed substantial cost and lead time reductions when using laminated injection-mold tools for the automotive industry. Reductions in cycle times and improved part quality were proven as a result of using conformal-cooling methods.

A collaborative project between Warwick Manufacturing Group, Loughborough University, and De Montfort University showed up to a 50% cost reduction and a 54% time savings when using laminated tooling to produce gravity and high-pressure die-casting tools.

Another organization that used laminate tooling is Innova Engineering GmbH. Innova manufactures the Contura System, which has been used in industry for many years. The process involves computing the temperature profile of the part in order to determine the cooling behavior of the tool. Conformal-cooling channels can then be designed accordingly. The tool is built up from machined plates that are bonded together using a patented vacuum furnace brazing technique. Bayer Plastics used this technique for some time and reported reductions in cooling time of 20–40%.

Tokyo Institute of Technology was also involved in laminate tooling. The institute produced laminate tooling using thin sheets of steel. The Stratoconception process, developed by Cirtes, is useful for large tools, and was used by several companies to manufacture tooling.

Space Puzzle Molding

Protoform GmbH, (Fürth, Germany), developed a technology called Space Puzzle Molding (SPM). SPM enables a molder to produce injection-molded prototypes and low-volume production parts from the tooling.

The Space Puzzle Mold and the patented mold-holding device makes SPM unique. The mold is designed with normal parting lines so that it fits together like a puzzle. The molds are easy to build and change, according to Peter Hofmann of Protoform GmbH. No ejector pins or mechanical mold slides are necessary, even for complex parts. Each mold is relatively small and compact in comparison to a conventional mold.

SPM molds are normally CNC machined from aluminum or steel. The production limit of a Space Puzzle Mold is usually 500 to 1,000 parts—determined primarily by the complexity of the part. The maximum quantity is approximately 5,000 pieces. The SPM mold does not require a mold base because of its mold-holding device.

Small molds are hand loaded into the mold-holding device, but the larger molds require mechanical assistance. After each cycle of the injection-molding machine, the molds are unloaded and disassembled to remove the part. SPM can also be used for multi-material molding, structural foam molding, and gas-assist molding. SPM is capable of injection molding production-quality prototype parts in virtually any thermoplastic material, at normal molding conditions, Hofmann said.

Reconfigurable Tooling Systems

Reconfigurable Tooling Systems (also known as Reformable Tooling Systems) is based on proprietary state-change materials that were developed by 2Phase Technologies (Dayton, Nevada). The state-change material consists of a mixture of particles and liquid. This solid and liquid combination creates a fluid-like mixture that can be transitioned to a solid state when the liquid is removed by surrounding the material with thin latex and pulling a vacuum. Following the transition to the solid state, the material forms a stable ceramic with the addition of heat. The ceramic can be returned to a fluid state at any time with the reintroduction of the liquid.

2Phase Technologies used the process to develop single-sided tools for composite layup, thermoforming, and urethane castings. The process gained attention commercially, but apparently not enough. After several years and some machine sales in the automotive and military industries, the venture capital company behind 2Phase pulled the plug on the company.

Others

Express Tool is an electroforming technology that was launched in 1996. The Infinite Group, Inc. owned Express Tool, as well as Laser Fare and Infinite Photonics. In 1999, Infinite purchased a 50-year-old tooling company named Osley & Whitney, and this is where Express Tool was "housed." Osley & Whitney went out of business in 2001, and work on the Express Tool process stopped when the company folded. Prior to ceasing operations, little, if any, work had been done with the technology in many years.

Many years ago, CEMCOM Corp. developed an electroforming process of producing prototype and bridge tooling for plastic injection molds. In 2000, the company was shut down. The same year, Sean Wise, former R&D director at CEMCOM, established a new company named RePliForm (repliforminc.com) in the Baltimore, Maryland, area. The company has used the CEMCOM electroforming process to produce mold inserts, although this activity has been phased back. The electroforming process is now used mostly for coating AM parts to give them a metallic finish.

EcoTool is an indirect tooling process that was developed by the Danish Technological Institute (DTI), TNO Industrial Technology, and several companies. The process is similar to some other indirect tooling processes, such as PolySteel, except that it uses a different binder system that is capable of withstanding the high temperatures required for the infiltration of metal. Due to questions about property rights and other issues, work on the process stopped.

Years ago, Dynamic Tooling (Fresno, California) developed a powder-based approach called PolySteel. Using an AM pattern, the process produces mold inserts that consist of approximately 90% steel by weight. According to Paul Vawter, inventor and then president of Dynamic Tooling, PolySteel molds work for producing parts in virtually any thermoplastic material, including glass-filled nylons and ABS.

Risk factors

The "soft" methods, such as SL tooling and epoxy-based composite tooling, have a relatively high risk factor that one must consider. If a project has high importance (e.g., first-time customer, critical delivery, high repeatability), these processes may not be the best solution, even if the key criteria are satisfied. The tools themselves are easily damaged by the molding process and human error. With SL tooling, many tools have failed in the first ten shots, even though they were expected to last for 200. In many cases, it is worthwhile to invest in a more durable tool to ensure good results.

Another problem inherent to soft methods is that the mechanical properties of the parts they produce are not the same as parts made with production tools. One of the main reasons for building a prototype tool is for mechanical testing of prototypes. Because the molds are "pampered" to preserve the tool's life, the mechanical function of the molded parts is often compromised. Even though the properties may not match production results, however, users of these solutions find that the information gained is often extremely valuable.

It is difficult to anticipate problems that may result from a selected tooling solution, but it is important to do so. To yield the desired results, most unconventional methods of tooling require unique secondary steps to perfect the tool. These steps can require the addition of machining stock on a parting surface or shut-off so that the tool can be machined to specification. In the case of the powder deposition methods, the entire surface typically requires finish machining.

In conventional tooling, the process includes a sampling step where the injection-molded part is evaluated. In many cases, the tool is then modified to accommodate the behavior of the material and bring the parts into specification. Many of the rapid tooling solutions do not offer the same latitude in tool refinement. The solution can become a one-shot opportunity: get it right the first time or start over. So, the ability to predict the performance of the tool from the tooling method can be critical to a project's success.