Cast metal parts

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Additive manufacturing processes have long had applications in metal casting. Since the first systems emerged, attempts have been made to use the capabilities to reduce both the time and cost of creating metal castings. The success of AM techniques in metal-casting applications varies considerably from one casting process to the next.

Investment casting

Of all the metal-casting methods, AM technologies have had the greatest impact on investment casting. Virtually any AM process is capable of making patterns for investment casting. Some work much better than others, however, and the majority of patterns are created by one of following additive technologies:

QuickCast: This is a stereolithography build style that produces semi-hollow patterns. These patterns implode during the burn-out process, preventing the cracking of the ceramic shell. It remains a popular option, especially in North America, and is the most common form of 3D-printed pattern for metal castings. QuickCast patterns, in general, provide very good accuracy and surface finish.

The QuickCast build style was intended to allow the pattern to collapse during the autoclave step. It also helps in burnout by reducing the mass of material that must be removed, thus reducing the amount of ash.

Vat photopolymerization: In addition to QuickCast from 3D Systems, a growing number of manufacturers and material suppliers offer photopolymers for investment-casting applications, including Envisiontec, DWS, Asiga, Rapid Shape, Carima, and DSM Somos.

Material jetting: Solidscape was the first company using the material-jetting process to offer investment-casting patterns, and remains a popular choice, especially for the jewelry industry. 3D Systems offers wax VisiJet materials for its ProJet CP and CPX multi-jet modeling systems.

Laser sintering: LS processes from both EOS and 3D Systems are used to create polystyrene parts that are then sealed with molten wax.

ThermoJet: The ThermoJet printer was discontinued by 3D Systems many years ago, but the few ThermoJet systems still in service are used to make patterns for investment casting. The process has significant limitations in accuracy, but the wax parts the process creates are easy for most foundries to cast.

Voxeljet: Voxeljet's binder jetting systems are also capable of producing investment-casting patterns in a polymethylmethacrylate (PMMA) material.

New technologies have been introduced in recent years and should grow in popularity. 3D Systems' ProJet CPX and CP printers are examples. The CPX is a high-resolution machine designed for small parts such as jewelry, dental, and medical parts. The CP version is targeted at general foundry applications. Both have the advantage of building directly in wax, which makes it easier for foundries to process the patterns.

AM processes are also used to create tooling for molding wax patterns, although this application has not yet shown enough advantage to gain wide acceptance.

Investment-casting patterns from AM processes are used in the following four main areas:

Prototype castings: Patterns from AM allow castings to be created without the investment of time and money in pattern tooling. Consequently, companies can quickly and inexpensively create near-production quality prototypes to test a design. These patterns for prototyping allow designers to evaluate several competing designs simultaneously. Also, designers can produce more design iterations than are possible using conventional wax pattern tooling.

Process development: A number of steps in the development of the casting process require patterns or castings. Consequently, they are typically not completed until after the delivery of wax pattern tooling. Such steps include optimizing gate locations, optimizing casting assemblies, determining local shrink values, robotic dip programming, and designing straightening fixtures. By using AM patterns, all these steps can be completed prior to delivery of the tooling, allowing faster delivery of the production castings.

Initial delivery of production castings: The quality of AM patterns, especially SL patterns, has improved to the point where they rival molded wax patterns. In fact, they are accepted in many industries for production casting applications. Consequently, foundries can use these patterns to create initial deliveries of castings while wax pattern tooling is being produced.

Low-volume production castings: With the ability to create production-quality patterns without the need for wax pattern tooling, investment casting is now able to effectively compete with the machining of low-volume metal components. Previously, investment casting could not be justified for low volumes due to the cost of tooling. For more complex shapes, investment casting with AM patterns can provide significant savings in both time and money compared to machining. A number of foundries are taking advantage of this new market. Low-volume production castings also provide better margins than conventional investment casting. Low-volume production is less likely to experience significant foreign competition.

The last two categories have grown steadily. An estimated $40 million is being generated annually from investment-casting patterns built using AM processes. Note that this is the value of the printed patterns and not the castings, which would be a much larger number.

The use of AM patterns has gained widespread acceptance. Since 2000, the percentage of investment-casting foundries that have developed the ability to use AM patterns has increased from about 5% to more than 95% in North America. It is lower in Europe and Asia.

AM has especially taken hold in the jewelry industry. It is believed that thousands of AM systems are now in use making patterns for jewelry. In 2007, an estimated 2 million jewelry patterns were created on AM systems annually, resulting in the creation of more than $500 million worth of jewelry (excluding the value of the gemstones that are added). These numbers have since grown.

Sand, V-Process, and plaster mold casting

Sand, V-Process, and plaster mold casting are similar in that they all create cope-and-drag-type tooling and use inserts (called cores) to form undercut features. They differ primarily in the mold material used and the manner in which the mold is created. In each case, the mold is used once and destroyed in the process of retrieving the casting.

Sand casting uses either compacted green sand or a chemically bonded sand to form the mold. It is the most widely used casting process and can be used for a wide variety of alloys and part sizes. The V-Process uses unbonded sand for its molds. The mold is held in shape using a thin film of plastic and a vacuum. The plaster mold casting process is very similar to sand casting except that plaster is used as the mold material instead of sand. All three processes use very similar tooling, called patterns, to create the mold. Different levels of complexity to the tooling are needed, depending on the number of molds that will be made.

AM processes are also used to create core tooling. As was previously mentioned, cores are loose pieces placed in a mold to form undercut features and internal geometries. Cores are typically made of chemically bonded sand or plaster and are formed in molds called coreboxes. Cores are placed in molds very much like hand-loaded inserts are placed in a simple injection-molding tool. AM processes have been used to make simple coreboxes directly, and also to make patterns against which epoxy coreboxes are cast.

Systems that create molds and cores directly

A number of manufacturers have developed AM processes that build in plaster or sand directly. Using these systems, molds and cores can be built directly, eliminating the need for patterns and coreboxes. EOS, ExOne, 3D Systems, and Voxeljet have offered systems that are capable of creating molds and cores. EOS discontinued its EOSINT S sand system at the end of 2014.

Sand printing has gained acceptance as the fastest and least expensive way to create prototype sand castings. The cost of the machines is higher than most foundries can afford, but many service providers produce and sell printed molds and cores around the world.

Die casting

Die casting is the metal equivalent of injection molding. Die-casting tools have been produced using methods from POM, EOS, and others. Some of the tools have been successful, while others have not. Given the pressures and temperatures required in die casting, it is unlikely that AM processes will replace machined tooling in the foreseeable future.

AM processes are most often used to create prototypes of components that will ultimately be die cast. Patterns produced additively are often used with sand casting or plaster-mold casting to create prototype castings. Although sand- and plaster-mold castings often have significantly different properties than die-cast production components, they are sufficient for many prototyping applications.