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Sand Casting Applications Using Rapid Prototyping Technology

By Stratasys, Inc.

Using PolyJet™ technology for sand casting applications can increase cost savings, reduce product development time and engender new design developments. The Stratasys® line of 3D printers that use PolyJet technology brings high-resolution rapid prototyping solutions to casting environments. Sand casting is typically used for processing low-temperature metals, such as iron, copper, aluminum, magnesium and nickel alloys. It can also be used for high-temperature metals when other means would be impractical. The sand used in this process is bonded together using clays or chemical binders.

Castings are then machined to produce finished products or components. In most operations, the sand can be recycled many times, each time requiring the addition of only small amounts of sand. Sand has almost no upper limit on part weight, and minimum part weight ranges from 0.075–0.1 kg.

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Sand casting is by far the oldest and best understood of all casting processes. It is also less expensive than dye and investment creating rough metal parts. While sand mold preparation is fast, it requires a pattern that can "stamp" out the casting template. Sand casting may require a longer lead time for production at high output rates (1–20 pieces/ hour/ mold) but it is unsurpassed for large-part production. As such, the production process can be automated, although it is somewhat less easy to automate the design and preparation of forms.

INTRODUCTION

In the sand casting process, a pattern is made in the shape of the desired part. This pattern can be easily made using models using PolyJet materials. A single piece or solid pattern is used for simple designs. More complex patterns made from two parts are called split patterns.

The pattern can also be designed in the CAD level and printed on a Stratasys 3D Printer. The upper part of a split pattern is called a cope; the bottom section is called a drag. (See Figure 1.) Where the cope and drag separate is known as the parting line. Both solid and split patterns can have cores inserted to complete the final part shape. When making a pattern, it is necessary to taper the edges so the pattern can be removed without breaking the mold.

Forming the Cavity: The pattern is housed in a box called the flask and then packed with sand. A binder helps harden the sand into a semi-permanent shape. Once the sand mold is cured, the pattern is removed. This leaves a hollow space in the shape of the desired part in the sand. The pattern is made larger than the cast to allow for shrinkage during cooling. Sand cores can then be inserted in the mold to create holes and improve the casting's overall shape. Simple patterns are usually open on top, allowing molten metal to be poured into them. Two-piece molds are clamped together.

Molten metal is poured into a pouring cup from where it travels down a channel called a sprue and into the gating system. Vent holes are created to allow hot gases to escape during the pour. Ideally, the pouring temperature of the molten metal should be a few hundred degrees higher than the melting point, assuring good fluidity. This temperature difference also prevents premature cooling, which can cause voids and porosity.

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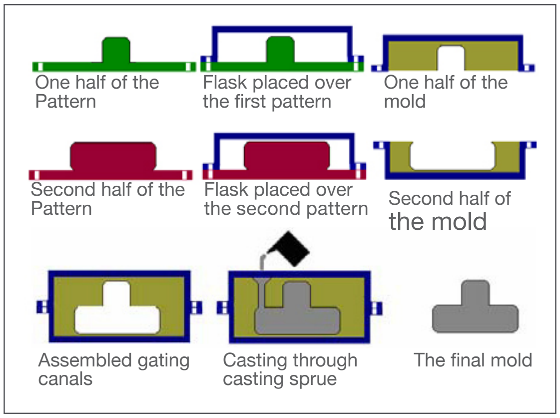

Figure 1: Workflow of the sand casting process

After the metal cools, the sand mold is removed and the metal part is ready for additional operations, such as cutoff and grinding.

Figure 1 illustrates the sand casting process in which the master model is a 3D printed model.

Sprues and Runners: The molten material is poured into the pouring cup, which is part of the gating system that directs the molten material to the mold cavity. The vertical part of the gating system connected to the pouring cup is the sprue; the horizontal portions are called the runners. The multiple points where the material is introduced to the mold cavity are called the gates. Additionally there are extensions to the gating system, called vents, which provide an outlet for the built-up gases and the displaced air to vent.

The cavity is usually made oversized to allow for metal to contract as it cools to room temperature. To allow for shrinking, the pattern must be oversized according to certain averaged factors. There are linear factors that apply in each direction. These shrinkage allowances are only approximate because the exact allowance is determined by the shape and size of the casting. In addition, different parts of the casting might require different shrinkage allowances.

Sand casting facilities use a 3D printer to create mold patterns as they offer high-resolution printing and utilize materials that fit the requirements of this application niche. Stratasys' 3D Printers that use PolyJet technology offer exceptional ROI for professional rapid prototyping applications. For example, the Connex and the Eden systems' high-speed printing of 16μ layers produces models with exceptionally fine details and smooth surfaces.

3D printers are designed to address disparate manufacturing needs in terms of build size and productivity and varying budget requirements. Their compact design and clean printing process are ideal in any office environment.

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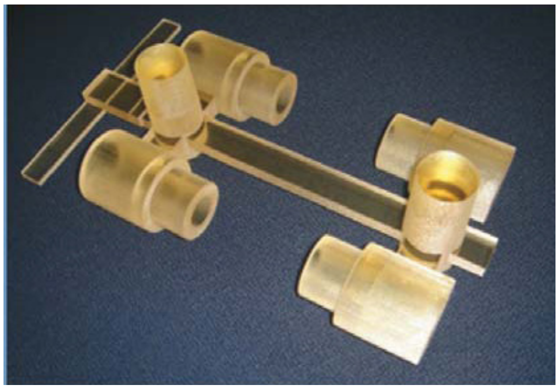

Figure 2: A 3D printed model using PolyJet Technology.

THE PROCESS

In general, the sand casting process includes a cast part produced by forming a mold from a sand mixture and pouring molten liquid metal into the cavity in the mold. The mold is then cooled until the metal has solidified. In the last stage, the casting is separated from the mold. There are six steps to this process:

1. Place a pattern in sand to create a mold.

2. Incorporate a gating system.

3. Remove the pattern.

4. Fill the mold cavity with molten metal.

5. Allow the metal to cool.

6. Break away the sand mold and remove the casting.

There are two main types of sand used for molding: green sand and dry sand. Green sand is a mixture of silica sand, clay, moisture and other additives. Dry sand is sand bonded to materials other than clay with a fast-curing adhesive. When dry sand is used, the castings are called air-set sand castings.

With both types of sand, the sand mixture is packed around a master pattern, forming a mold cavity. If necessary, a temporary plug is placed to form a channel for pouring the fluid to be cast.

Air-set molds often form a two-part mold with a top and bottom, termed cope and drag. The sand mixture is tamped down as it is added. The final mold assembly is sometimes vibrated to compact the sand and fill any unwanted voids in the mold.

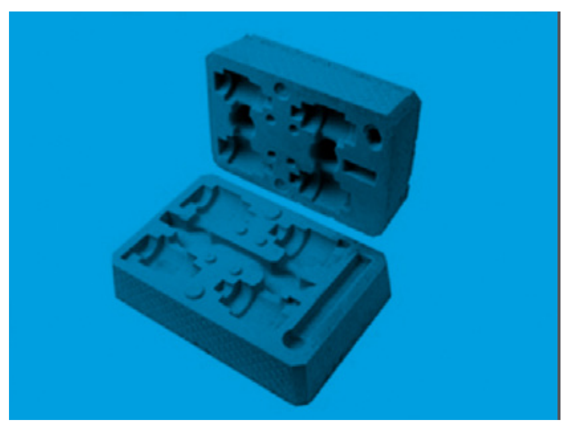

Figure 3: A sand casting mold Properly locating the parting line

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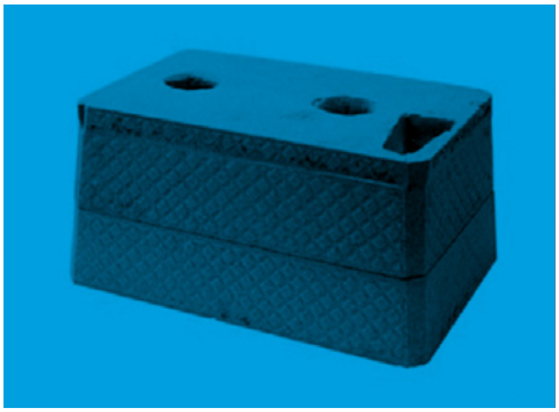

Figure 4: The pattern is removed from the mold

The pattern is then removed with the channel plug, leaving the mold cavity. The casting liquid (typically molten metal) is then poured into the mold cavity. After the metal has solidified and cooled, the casting is separated from the sand mold. There is typically no mold release agent and the mold is usually destroyed in the removal process.

The accuracy of the casting is limited by the type of sand and the molding process. Sand castings made from coarse green sand have a rough surface texture, making them easily identifiable. However, these surfaces can be ground and polished to eliminate the roughness.

During the thermal casting process, some of the components of the sand mixture are lost. After adjusting the sand's composition to replenish lost moisture and additives, the sand can be reused. The pattern itself can be reused indefinitely to produce new sand molds.

Properly locating the parting line reduces the number of cores and the amount of waste while increasing dimensional accuracy. Uniform casting thickness results in uniform cooling and solidification, as well as distortion-free castings.

When uniform cross sections cannot be maintained, gradual changes in cross sections are required. This can be achieved by using a transition radius of one-third of the thicker section and blending in the radius with a 15-degree slope line. To minimize problems at intersecting points within the core, it is recommended that staggered rather than continuous ribs are used and that large, unsupported areas be avoided. Maintaining minimum wall thickness will prevent voids and non-fill areas.

With a solid understanding of the process and its advantages, one can confidently select sand casting as the preferred low-cost method for creating metal components.

The end product can be made of ductile iron, gray iron, steel, stainless steel, aluminum or brass.

CONCLUSION

The advantages of sand casting are: an inexpensive casting process compared to machining, dye casting and investment casting; and the ability to use most metals and alloys. The drawbacks of sand casting are that one can cast only basic part shapes; castings produce a rough surface finish; and they require secondary machining.

Viewed in this light, sand casting offers the simplest method for the production of non-ferrous castings and for the production of small numbers of castings with a low tolling cost.

It produces less waste than a number of other machining processes because the material can be reused in subsequent molds. Furthermore, it can achieve a wide range of shapes with a short turnaround time, especially when based on previously used molds or standard designs. Taken as a whole, the sand casting process is often far less expensive than other techniques and one of the fastest methods available.

Sand casting's limitations include a low casting rate and minimum wall thickness of about 3.5 mm. It also suffers from the disadvantage of producing a product that requires further machining. However, most applications require additional post-process finishing such as grinding and plating anyway. These post-processes create a finer surface, particularly important when the casting product will be used as a visible component. The advantages of sand casting, therefore, outweigh its drawbacks.

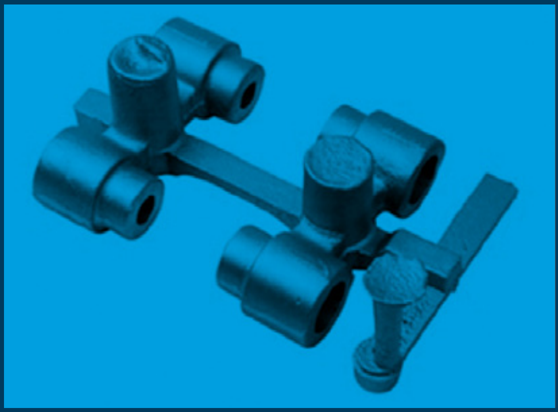

Figure 5: A brass casting product

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