STRATASYS®

Sand Casting

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Overview

For sand casting, the most common metals are iron, steel, bronze, brass and aluminum. With these alloys, sand casting can produce small parts that weigh less than one pound or large parts that weight several tons. The process is used to make medium to large parts such as valve bodies, plumbing fixtures, locomotive components and construction machinery. Its versatility also allows sand casting to produce small parts such as buckles, handles, knobs and hinges. It is a cost effective and efficient process for small lot production, and yet, when using automated equipment, it is an effective manufacturing process for high-volume production.

This process guide describes the application of Fused Deposition Modeling (FDM®) to automated (flaskless) casting with green sand. However, the information provided is also applicable to flask casting and dry sand.

FDM and Sand Casting

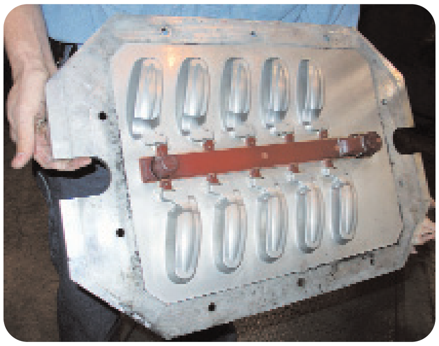

Figure 1: Machined aluminum matchplate.

Figure 2: FDM matchplate, mounted in automatic molding machine, can withstand the ramming forces used to pack sand casting tools.

The sand casting process is relatively simple, and the production of the sand molds and cast metal parts is relatively quick. However, the fabrication of the patterns to produce the sand molds can be time consuming. The application of FDM to the sand casting process reduces the pattern development time to expedite the receipt of prototype or production sand cast parts.

There are three approaches to sand casting patterns: loose patterns, cope and drag patterns and matchplates. Loose patterns are simply a pattern representing the cast piece. Cope and drag patterns incorporate the part pattern and the gating system. Matchplates combine both the cope and drag patterns in one integral piece. Commonly, these are machined patterns made of wood or aluminum (figure 1).

To replace the machined pattern with rapid prototyping, it must be able to withstand the chemicals in the sand, be abrasion resistant and be able to withstand the ramming forces that are applied to pack the sand (figure 2). Unlike many other rapid prototyping technologies, FDM meets these requirements with its ABS, PC (polycarbonate), PC-ABS blend and PPSF/PPSU (polyphenolsulfone) materials.

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When used for pattern production, FDM reduces the lead time from weeks to days while offering cost savings. Since FDM is an automated, unattended process, sand casting foundries also increase overall efficiency and productivity while reducing labor costs.

An additional benefit when using FDM for sand casting patterns is that there is no change in tool design, the tool making process or the casting process. The benefits are delivered by simply replacing machining with FDM while retaining standard design practices and manufacturing procedures.

Figure 3: Representative sample of Melron Corporation's door and window hardware.

Application Brief

Melron Corporation manufactures window and door hardware, including handles, hinges and pulls (figure 3). In its pilot run, Melron used an FDM matchplate, made in ABS, to create 96 sand casting molds. Satisfied with the results, the pilot run was halted. However, Melron Corporation believes that, conservatively, this matchplate could produce 5,000 sand casting molds.

The matchplate, which measured 26.0 x 17.5 inches (660 x 445 mm), was completed in one week. Previously, this matchplate would have been machined in aluminum by a subcontractor and would have taken six to seven weeks. Melron also determined that it saved $500 on the cost of the matchplate. With the easy and automated operation of FDM, this solution for pattern making offers the Melron the opportunity to gain control over the entire process by bringing matchplate production in-house.

Speed and flexibility are critical to any manufacturer, but for Melron, fast, flexible and cost-effective solutions are imperative. Due to offshore competition, the company is realigning its business focus. Instead of making stock items with long product lifecycles, it is turning its attention to hardware for the residential and restoration markets. The FDM solution enables Melron to rapidly and affordably deliver small lot production of custom made hardware.

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Beyond mold making, Melron also envisions FDM as a sales tool and a manufacturing aid. When submitting a bid on a custom project, the company plans to include electroplated FDM prototypes to demonstrate its concept to the prospective buyer. Melron also plans to incorporate FDM fixtures in its machining operations. Production castings would be clamped into an FDM fixture for finish machining.

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Process Overview

In sand casting, there are two components to the tool. The cope is the top side of the tool. Depending on the type of metal that is poured, it may incorporate the sprue, gates, vents, risers and filters. The drag is the bottom part of the tool. Like the cope, its design is dependent on the cast metal. Usually, the drag incorporates the runners, gates and wells. When undercuts are present, or if the cast part has hollow areas, loose cores, which are also made of sand, are inserted into the cope and drag.

The process begins with the design of the cast part and the metal delivery pathways in the mold. This data is then used to construct a pattern that forms the cope and drag. The pattern is mounted in a four-sided box called a flask. Sand is then poured into the flask, and it is packed tightly against the pattern. Binders, which are either clay (green sand) or chemical agents (dry sand), hold the compacted sand together.

Molten metal is poured into the mold through the sprue. It flows through the runners and gates into the part cavity. The metal also fills the riser, which acts as a reservoir that continues to feed the part cavity as the metal cools and shrinks. The metal is then allowed to cool and solidify, and the sand is broken away from the parts.

Although relatively simple in concept, sand casting requires a great deal of experience. The challenge is to design a tool that provides suitable pathways for a sufficient, non-turbulent flow of metal into the part cavity and has proper venting for the release of any gases. Failure to do so will yield a casting with voids and imperfections. Using FDM for pattern creation, sand casters have an efficient and effective way of prototyping the tool design, and when perfected, proceeding directly to production casting.

Figure 4: Green sand, as shown here, retains its shape when compacted.

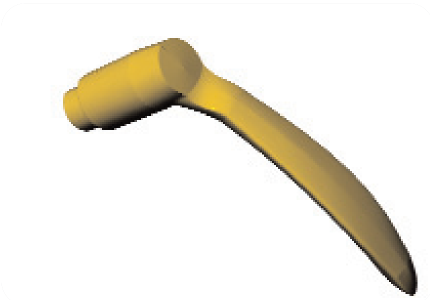

Figure 5: CAD file of door handle with draft and shrinkage allowance.

Figure 6: For split patterns, the CAD file is separated along the parting line.

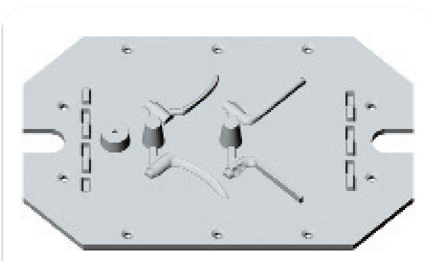

Figure 7: Matchplate (cope side shown) with mounting holes, alignment locaters, gates, risers and sprue mounting pad.

"Using FDM for pattern creation, sand casters have an efficient and effective way of prototyping the tool design, and when perfected, proceeding directly to production casting."The following process describes the steps required for sand casting with green sand (figure 4) that is packed in a Hunter Automatic Molding Machine. This machine uses matchplate patterns. However, these steps can be used for dry sand applications that use loose cores or cope and drag patterns. It is also adaptable to manual sand packing processes.

As the guide details, there is no need to change any element of the sand casting process when using FDM patterns. Pattern design, tool making and metal casting are all done as they would be with any other pattern.

"There is no need to change any element of the sand casting process."

Process

Design Matchplate

The first step in matchplate design is to modify the cast part's geometry for the sand casting process (figure 5). The part is scaled to accommodate metal shrinkage during the casting process and material removal in the finishing operations. Shrink rate varies by alloy and part geometry, but it typically ranges from 1.0 to 1.5 percent. After defining the parting line, draft is applied to the part. Typically two degrees, the draft allows the pattern to be removed from the cope and drag.

The matchplate size and configuration are specified by the automatic molding machine. In this case, the matchplate base is a solid slab that measures 26.0 x 17.5 x 0.5 in. (660 x 445 mm x 13 mm). For mounting to the molding machine, "u-shaped" cutouts are added to both ends, and countersunk holes are placed around the periphery of the matchplate.

Matchplates use split patterns (figure 6). The part file is separated along the parting line and the two halves are added to the matchplate base. The half that forms the cope side of the tool is joined to the top face of the matchplate, and the drag side is placed on the bottom face. Next, runners, gates, risers and wells are added. To align the cope and drag, locators are also added to the matchplate. For storage purposes, this tool uses a removable sprue, so a mounting pad is placed where the sprue will be attached (figure 7). Following the construction of the FDM matchplate, a threaded insert is placed in the mounting pad to accept the sprue.

An alternative, which further decreases time and cost, is to use FDM inserts that are mounted to a prefabricated matchplate blank. With this approach, a pattern for the part and gating is constructed in FDM. It is then mounted to a standard matchplate base that has the sprue, runners and risers.

Build Matchplate

Due to the size of the matchplate, it was constructed in an FDM Maxum® machine that makes the pattern in ABS (figure 8). If the insert concept were used, the smaller size would allow construction in a Vantage™ or Titan™ with polycarbonate (PC), PC-ABS blend or polyphenolsulfone (PPSF/PPSU). Use of these high temperature, tough materials would extend the pattern life and increase the number of molds.

To construct the matchplate, use standard build parameters. Note that due to pack-ing pressures, sparse fill is not recommended.

In many cases, a good build orientation will eliminate the need for sanding of the FDM matchplate. If this is true, the matchplate is prepared with the application of Master™ Foundry-Kote™, or a similar product. Foundry-Kote, which provides an

Figure 8: FDM matchplate made in ABS with sprue attached.

Figure 9: The FDM matchplate is mounted to the automatic molding machine's pattern frame.

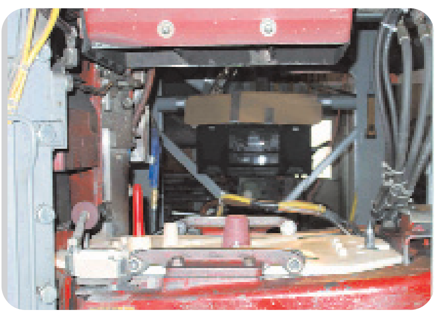

Figure 10: FDM matchplate is raised and mated with the flask for packing the sand casting tool.

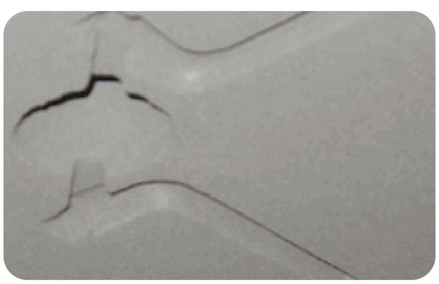

Figure 11: Matchplate impression in the mold.

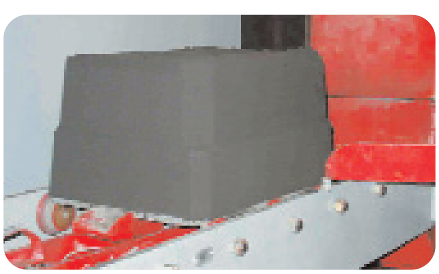

Figure 12: Assembled mold is transferred to the pouring station..

abrasion resistant and lubricating face coat, will smooth the surface of the matchplate. Two applications of Foundry-Kote are recommended. Following each coat, allow the Foundry-Kote to dry for 24 hours.

Should ripping—sand adhering to the matchplate and breaking away from the cope or drag—occur when packing the tool, apply another coat of Foundry-Kote or sand the area and reapply the Foundry-Kote.

Construct Sand Casting Tool

The matchplate is bolted to the molding machine's pattern frame (figure 9). The automated process conveys the matchplate to the molding station where it is mated with the drag flask. Sand fills the flask, and a hydraulic ram compress the sand at a pressure of 500 psi (3.4 MPa) (figures 10 and 11). The matchplate is retracted; the drag is transferred from the molding station; and the matchplate is inverted. It is then mated with the cope flask, and the process is repeated.

Metal Casting

The cope and drag are assembled to make the mold (figure 12). It is transferred to the furnace area where the molten metal is poured (figure 13). The parts illustrated in this process guide are made of brass. However, aluminum has also been cast with tools produced from FDM matchplates.

Following the pour, the metal is cooled. When solidified, the sand is removed using a vibratory process (figures 14 and 15). The rough castings are then inspected by foundry personnel. Following inspection, the gates, runners and risers are cut off. The castings are then ground to remove excess flash and tumbled to smooth the surfaces.

The production sand cast parts are then machined, assembled and finished (figure16).

Conclusion

By replacing machined patterns with FDM matchplates or matchplate inserts, companies can move from tool design to production sand castings in as little as one week. This simple substitution requires no change to a foundry's practices and procedures, yet it offers significant reductions in the time to produce end-use parts.

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Implementing FDM in the tool making process also increases throughput and operational efficiencies. Rather than staffing CNC machining centers, a foundry's employees can be allocated to other operations since FDM is an unattended and automated process.

Sand casting has been used for centuries with little change to the basic process. Today, the process can be improved with FDM, which enables high volume production and make low volume production of custom pieces feasible. Sand cast iron, steel, brass, bronze and aluminum parts can be produced in less time than previously possible.

Figure 13: Crucible, filled with molten bronze, just prior to pouring into the mold.

Figure 14: Raw casting surrounded by loose sand after the vibratory process.

Figure 15: Raw bronze casting, with gates, runner, riser and sprue, is ready for machining.

Figure 16: Finished parts.

More Info

Solidworks was the CAD software used to prepare the parts and matchplate. www.solidworks.com

Melron is a family based foundry located in Wisconsin. Debbie Flood, CEO/Owner, Gene Pagel, President and Brian Meliska, Product Engineer

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Author Acknowledgement

Susan Sciortino came to Stratasys in 1995 as an Application Engineer. She has a Business degree in Management, with a minor in Sales and Marketing, as well as a degree in Technology. Initially she worked on the Prodigy/Dimension systems development team, worked on the material flow control projects, software and hardware development teams, and performed extensive on-site customer training. In 2001 Susan became a Senior Regional Applications Engineer, and has recently changed positions to North American Sales Executive.

Wayne Meyers has been with Stratasys 3 years as an Application Engineer. He has a Bachelor of Science degree in Industrial Technology and Fluid Power Technology. He is certified on the Stratasys T-Class and Maxum systems and has extensive training in SolidWorks and Materialise Magics programs. His focus at Stratasys includes: accuracy, Best Practices team leader, Insight software team, customer revisits and on-site training, applications, and sealing and bonding.

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