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# CASTING MADE EASY WITH 3-D PRINTS

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## CASTING MADE EASY WITH 3-D PRINTS

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### Abstract

Sand Casting consists of filling a cavity mold with molten metal to form a metal cast. The cavity is made by packing sand around a pattern that is placed in a core box. The production of a pattern and the mold can be fairly time consuming. The use of 3-D printers in the classroom can eliminate this process and at the same time provide a rich hands-on casting experience for the students. In this project, students are taught the fundamental concept of casting followed by a casting project, involving the use of a 3-D printer to produce the mold, and completing the project with the pouring of low temperature materials into the 3-D mold to obtain the metal cast.

### Introduction

Manufacturing Process is one of the mechanical engineering courses that a mechanical engineering student will enroll to learn about traditional and advanced material processes. One of the topics covered in this course is the metal casting process in which sand casting is introduced.

In sand casting, molten metal is poured into a mold. This sand mold is created by packing sand around a pattern. The pattern is typically made out of wood. When the pattern is removed, the cavity that forms on the sand remains in the box. The cavity and sand combination forms the drag or the bottom half of the mold. Molten metal is usually poured through a channel called the sprue. This sprue is connected to a runner that will carry the molten metal into the cavity. Connected to the runner system is a riser that allows gases to escape. Excess molten metal also rises up through this outlet, acting as an additional source of metal during solidification. The sprue and the riser form the cope or the top half of the mold.

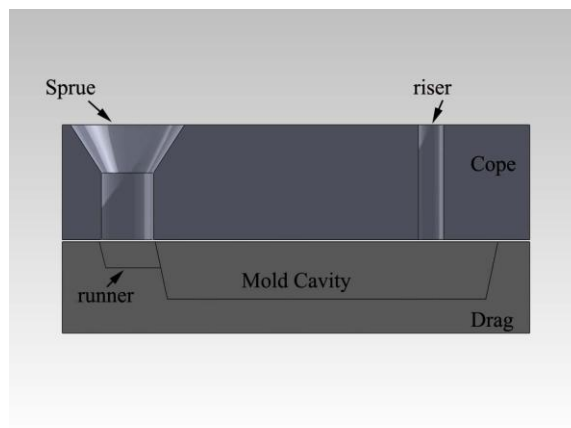


Figure 1. Typical components of a two-part sand casting mold.

In the sand casting lesson, students are taught about the design considerations for the patterns and the mold. Design considerations include incorporating geometric features and tolerances into the part and the mold. According to Kalpakjian & Schmid [1], design of castings usually involves the following steps:

1. Design the part so that the shape is easily cast.
2. Select a casting process and a material suitable for the part size, dimensional accuracy, surface texture, and mechanical properties.
3. Locate the parting line of the mold or die.
4. Locate and design the gating system to allow uniform feeding of the mold cavity with molten metal, including risers and sprue.
5. Ensure that proper controls and good practices are in place.

Most manufacturing process textbooks have images to reinforce the learning process. But it is not easy to visualise the need to incorporate small draft angles on the sides of the object to allow easy removal of the casting or the elimination of sharp corners or thin sections. A hands-on casting project where the students design the object, create the two halves molds and pouring low temperature metal into the mold cavity to obtain the final casting would further help reinforce their learning experience. But making the pattern, the sprue and runner system as well as the two halves molds can be a fairly time consuming process.

3D printing is a form of additive manufacturing technology where a three dimensional object is created by successive layers of material. This technology has been around for more than a decade [2]. These printers offer product engineers and designers the ability to print parts and assemblies made of several materials with different mechanical and physical properties in a single build process. Engineers and designers can 3D print a prototype quickly and cheaply before they embark on the expensive business of tooling up a factory to produce the real thing. Advanced 3D printing technologies can yield models that closely emulate the look, feel and functionality of product prototypes [3].

One variation of 3D printing consists of an inkjet printing system. Layers of a fine powder are selectively bonded by "printing" an adhesive from the inkjet print head in the shape of each cross-section as determined by a CAD file. This technology can print color prototypes.

There are other 3-D printing technologies in the market. Each technology has its advantages and drawbacks, and consequently some companies offer a choice between powder and polymer as the material from which the object emerges. Generally, the main considerations are speed, cost of the printed prototype, cost of the 3D printer, choice of materials, color capabilities, etc.

These 3D printers allow students to efficiently model the casting right from their desktop and can create models of the pattern in a very short time. Printing the half molds directly from digital data eliminates the pattern and core box production steps. Low temperature metal can be poured directly into these 3D printed molds. Because it is easy to produce a pattern/part in a relatively short period of time, the Manufacturing Process Course at Andrews University incorporated this technology into a class project.

## Design Project in the Manufacturing Process Course

The Manufacturing Process course at Andrews University is a third year engineering class. Students taking this course are required to have finished their Engineering Graphics course where they were trained in the use of a Computer Aid Design, CAD, software such as SolidWorks or Autodesk or Creo Elements/Pro.

In the manufacturing process course, after the introduction of the sand casting fundamentals, the students were tasked to put their knowledge into practice by designing a suitable paper weight that could be manufactured by a casting process. Engineering students must work visually and it is important that they can represent objects in space with reasonable accuracy. As such the students were to design the paper weight models using any of the CAD software. The CAD drawings were then saved as a .STL file and sent to the 3-D printer. The 3-D printer does recognize other CAD formats such as .zbl, .bld, .sfx, .3ds, and .zpr.

In this paper, the authors use a Zprinter@310 Plus. This printer has a resolution of 300 X 450 dpi, and a vertical build speed of 25mm/hour. The layer thickness is 0.089 - 0.203 mm and the build size is 202 x 254 x 203 mm. Figure 2 shows the Zprinter. The physical size of the Zprinter is similar to a typical copy machine. The 3D printer uses a blend of foundry sand, plaster and other additives suitable for casting low temperature metals.



Figure 2. ZPrinter 310 Plus (image taken from [www.zcorp.com](http://www.zcorp.com))

In this project students were asked to design the sprue and risers in such a way that the casting can be removed without breaking the cope as shown in figure 3. In this way the two halves molds can be reused; unlike the typical sand mold that must be broken down to remove the casting.

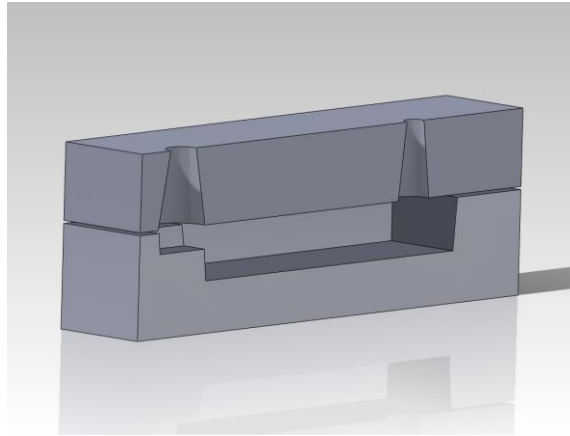


Figure 3. Section of the two halves molds showing the inverted sprue and riser for ease in removing the casting.

Printing of the CAD drawing took about two hours. This is followed by another couple of hours for the product to cure. Within 4 hours, the students could see, feel and touch the 3-D mold. The 3D printed molds are shown in figure 4.

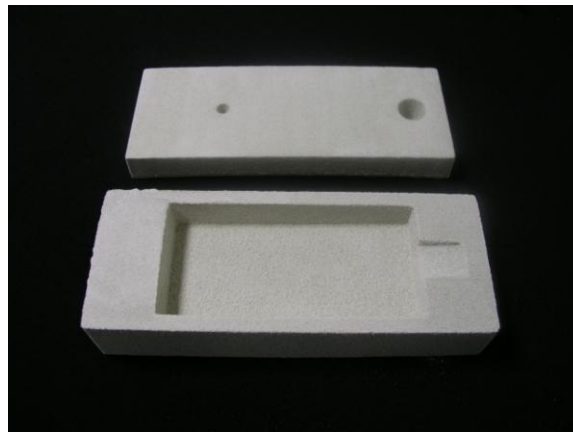


Figure 4. 3-D molds of a simple paper weight

The two halves molds were then held together by a simple G clamp to prevent molten metal from seeping through the parting line (between the cope and the drag). With proper safety attire, gloves and goggles, molten zinc alloy was slowly poured into the mold, as shown in figure 5, till the molten metal rises up through the riser. The castings were allowed to cool before removal from the mold. The casting, together with the two halves molds are shown in figure 6. Note that the surface of the casting has that grainy look and feel, just like a typical sand cast. This is because the mold compound has foundry sand in the mix.

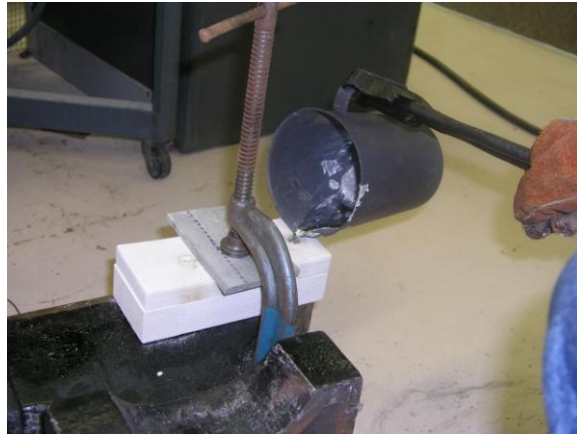


Figure 5. The two halves molds were held together by a G Clamp to prevent molten metal from seeping out of the parting line.

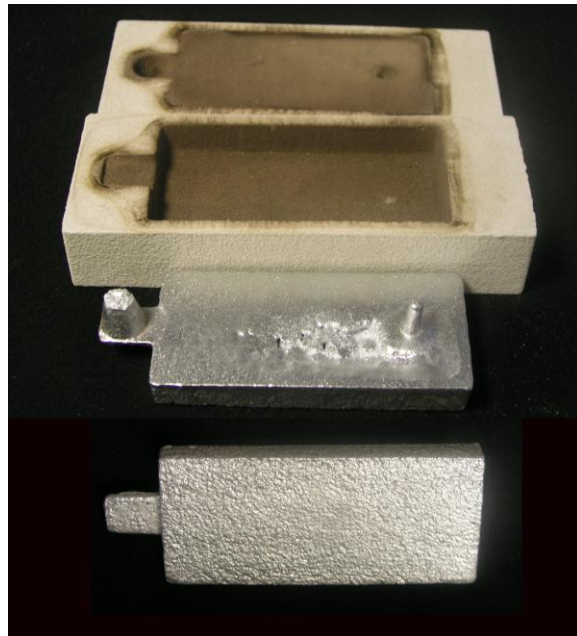


Figure 6. The cooled casting removed from the drag and the cope is shown with sprue and the riser. The other face of the casting is inverted at the bottom this figure.

In this project, some of the castings could not be removed from the mold. Students found that they had forgotten to provide draft angles in certain portions of the design. As such, some of these molds had to be broken to remove the castings (see figure 7). Students were able to examine the finished product and note any defects or mistakes that they had made. Figure 8 shows some of the casting defects such as misrun and flash.

Flash is a very common defect where the molds somehow separated enough to allow molten metal between the halves, along the parting line. Bruce, et al. [4] pointed out that the location of the parting plane is important, since the pattern must be extracted at this plane without disrupting the mold. Misrun is the failure of the metal to completely fill the mold cavity. This defect might have been prevented if the pouring of molten material into the mold was not interrupted during the casting process. Other defects observed in this project include cold shuts which is an interface in the casting that lacks complete fusion.

Once the casting was removed from the mold, the flash was removed, and the casting was given a secondary finish as shown in figure 9.



Figure 7. Breaking the mold to obtain the casting

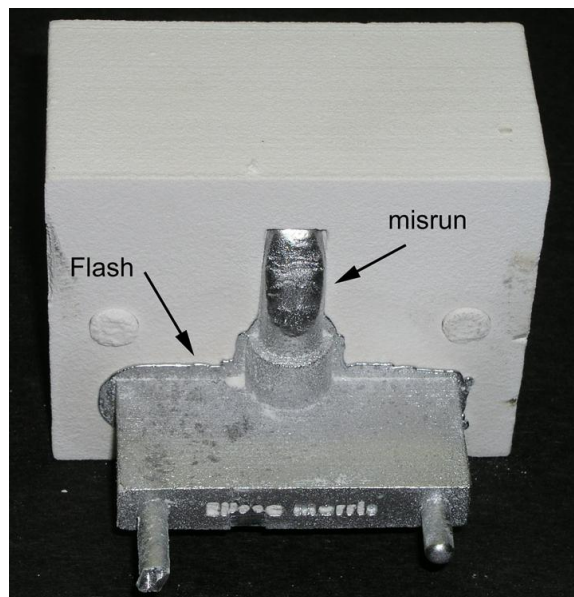


Figure 8. A portion of the casting protruding out of the mold. Misrun and flash were observed on this casting.

In this class project, students used the CAD software, 3D printer and a simple laboratory furnace to produce the casting in a relatively short period of time. With the hands-on experience the students understand the fundamental concepts and design of casting better.



Figure 9. The casted products, a) gear and mounting for the gear stand combination set and b) the half gear.

### Conclusion

3-D printers can create models of a design within 4 hours. These quick 3D models allow students in the Manufacturing Process Course at Andrews University to efficiently model and print their designs. With the 3-D models, students were able to see, touch and feel their prototype before proceeding to the casting process. With the finish cast component, the students were able to observe the defects that are common in casting processes and how such defects can be eliminated earlier in their design.

The class project utilizing the use of CAD software, 3-D printers and a simple laboratory furnace has been incorporated into the Manufacturing Process class at Andrews University to enhance the learning experience in the fundamental concepts of casting.

### Acknowledgement

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