Solutions to Homework Number Two
Due Wednesday October 21, 2015

1) Describe the green sand casting process. Include in your description a drawing showing all parts of a green sand mold. Explain the role of each part based on casting in general.

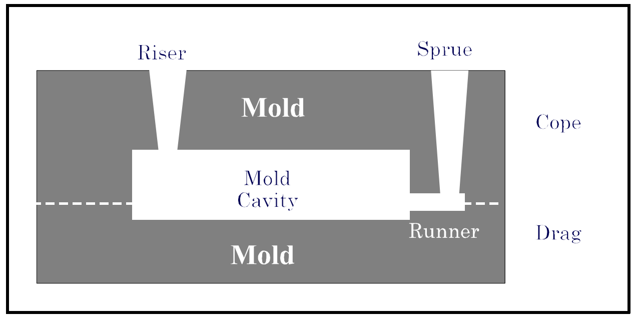


Figure 1: Green Sand Casting Mold

All casting processes are based on pouring molten metal (or other material) into a cavity (a well defined hole) and letting it solidify. An illustration of a green-sand cast mold is shown on the right in Figure 1. The mold is green sand; which is a mixture of sand, clay and binder material. The cope and the drag are metal fixtures which surround the green sand. The mold cavity is shown in the center is where the metal will solidify and form the part. Metal enters through the sprue and flows into the mold cavity through the runner. The runner is used so that molten metal will not destroy features in the mold cavity. A riser is often added to ensure that the metal in the mold cavity is not the last to solidify. This minimizes defects associated with shrinkage and in some ways serves as a sacrificial limb.

The green sand casting process consists of four steps: melting the metal, making the mold, pouring the metal, and removing the part once the metal has solidified The first, third, and fourth steps are self-explanatory and need little elaboration. Making the mold is the key step. A mold plate, containing the pattern of the mold cavity is placed upside down on the drag. The drag is then inverted. Talcum powder, sifted sand, and bulk sand are then placed in the drag. This is packed tightly. The drag is then turned right side up, and the cope is placed on the assembly. The sand packing process is repeated. The sprue and any necessary risers are added at this stage. The cope is then removed from the assembly, and the mold plate is removed from the top of the drag. If necessary runners are added. The cope is then placed on the drag and the mold is complete. Metal will be poured into the mold, and allowed to cool. Once cool, the sand is removed from the mold and the part is removed.

2) Compare the following casting processes: die, green sand, and investment (lost wax).

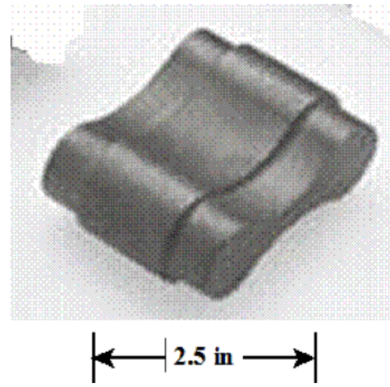
All casting processes are based on the same principle. Molten metal is allowed to solidify in a mold cavity, which can be described as a well defined hole. They differ in the way the mold and mold cavity are prepared from a pattern.

In die casting the die is a permanent mold (which includes the mold cavity). The molten metal is pushed into the die, allowed to solidify and removed. This process is automated.

In green sand casting the mold cavity is made by packing green sand around a pattern. The pattern is removed leaving a mold cavity inside a mold. Metal is poured into the mold. The mold is destroyed when the product is removed.

In investment casting the pattern is prepared from wax (which is easy to carve). The mold is prepared by placing a slurry followed by stucco onto the wax pattern. This is then exposed to high temperature such that stucco becomes a hard ceramic and the wax melts (thus forming the mold cavity). Molten metal is then poured into the ceramic mold allowed to solidify and frequently the mold is destroyed.

3) Which casting process (of the ones discussed in class) would you use to produce the part shown on the right? Assume you have a one year contract to produce 3500 parts per month and that a small amount of finish work to be done by the customer is acceptable.



The part shown in the HW is small and a limited amount of machining and/or sanding/polishing is possible. The key considerations are the following.

- What is required to make the mold pattern?
- What is required to make the mold?
- Is it possible to make multiple parts in one casting operation?
- What is the likely cost versus benefit?

As you read the answer on the next few pages please note, that there was a lot of copying and pasting. This shows how using a Word Processor can make your work more efficient and effective.

- Created a table and filled it out (not necessarily in order).
- Eliminated Lost Foam Casting and copied reasons to next to last page.
- Copied table and then eliminated the Lost Foam Casting row.
- Eliminated Investment Casting and copied reasons to next to last page.
- Copied table and then eliminated the Investment Casting row.
- Identified 3 Viable Processes and included them on the following page (using copy/paste)
- Added Suggestions on the same page as 3 Viable Processes by looking at notes.
- Copied Suggestions and Stuff on Next to Last Page to Final Answer and Revised slightly.

The final answer would be sufficient to get full credit on this problem.

A first analysis is shown below.

Process	Making Mold Pattern	Making Mold	Multiple Parts Possible	Likely Cost versus Benefit
Die Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Expensive Purchase Price including Die (Permanent Mold)
Green Sand Casting	Mold Pattern Made of Metal	Mold Made by Packing Green Sand around Mold Pattern	Due to Size the Pattern Could Contain Multiple Parts	Mold Destroyed During Each Operation.
Investment Casting	Mold Pattern Made of Wax	Mold Made by Placing Slurry then Stucco on Wax and then turning Stucco into Ceramic through High Temperature Exposure	Would have to be included when carving wax.	Mold and Mold Pattern Destroyed During Each Operation.
Lost Foam Casting	Mold Pattern Made of Polystyrene Foam	Mold Made by Placing Mold Pattern in Loose Sand. Mold Cavity Created as Molten Metal Evaporates Foam	Would have to be included when carving foam. Difficult to ensure molten metal would evaporate all parts.	Mold and Mold Pattern Destroyed During Each Operation.
Permanent Mold Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Creating Permanent Mold would be Expensive

Based on this analysis Lost Foam Casting, can be eliminated as a potential process. The work involved in creating each mold pattern, even if multiple patterns were possible would cost money and because both the mold and mold pattern is destroyed during each operation the work would have to be repeated. Finally, there is no guarantee that a foam pattern consisting of multiple parts would produce satisfactory multiple parts.

A second analysis is shown below.

Process	Making Mold Pattern	Making Mold	Multiple Parts Possible	Likely Cost versus Benefit
Die Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Expensive Purchase Price including Die (Permanent Mold)
Green Sand Casting	Mold Pattern Made of Metal	Mold Made by Packing Green Sand around Mold Pattern	Due to Size the Pattern Could Contain Multiple Parts	Mold Destroyed During Each Operation but Equipment Inexpensive Compared to Die or Permanent Mold Casting
Investment Casting	Mold Pattern Made of Wax	Mold Made by Placing Slurry then Stucco on Wax and then turning Stucco into Ceramic through High Temperature Exposure	Would have to be included when carving wax.	Mold and Mold Pattern Destroyed During Each Operation. The cost associated with creating the mold and mold pattern would make this process more expensive than Green Sand Casting.
Permanent Mold Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Creating Permanent Mold would be Expensive

Based on this analysis Investment Casting, can be eliminated as a potential process. The work involved in creating each mold pattern and mold even though multiple patterns are possible would green sand casting (where one patten is prepared) a less expensive alternative. This is especially true given that a small amount of finish work is acceptable to the customer.

A third analysis is shown below.

Process	Making Mold Pattern	Making Mold	Multiple Parts Possible	Likely Cost versus Benefit
Die Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Expensive Purchase Price including Die (Permanent Mold). Would the extra cost over Permanent Mold be warranted assuming contract renewal/increase.
Green Sand Casting	Mold Pattern Made of Metal	Mold Made by Packing Green Sand around Mold Pattern	Due to Size the Pattern Could Contain Multiple Parts	Mold Destroyed During Each Operation but Equipment Inexpensive Compared to Die or Permanent Mold Casting
Permanent Mold Casting	Not Needed	Mold Cavity Machined into Metal	Could be Included in Design of Mold Cavity	Creating Permanent Mold would be Expensive. Is the expense associated with making a permanent mold warranted. It would eliminate some finish work compared to Green Sand Casting.

Three Viable Processes

Die Casting: Mold Cavity Machined into Metal. Multiple parts Could be Included in Design of Mold Cavity. Expensive Purchase Price including Die (Permanent Mold). Would the extra cost over Permanent Mold be warranted assuming contract renewal/increase?

Green Sand Casting: Mold Pattern Made of Metal. Mold Made by Packing Green Sand around Mold Pattern. Due to Size the Pattern Could Contain Multiple Parts Mold Destroyed During Each Operation but Equipment Inexpensive Compared to Die or Permanent Mold Casting.

Permanent Mold Casting: Mold Cavity Machined into Metal. Multiple parts could be Included in Design of Mold Cavity. Creating Permanent Mold would be Expensive. Is the expense associated with making a permanent mold warranted. It would eliminate some finish work compared to Green Sand Casting.

Suggestions

Green Sand Casting would be the least expensive option. No specialized equipment must be purchased as would be necessary for die casting. Creating a mold pattern for multiple parts would be less expensive than creating a permanent mold for multiple parts. The cost of destroying the mold is not likely to exceed that of creating a permanent mold or purchasing either a die or die casting machine. The contract is only for one year.

Permanent Mold Casting could be warranted if one wanted to impress the customer due to less finish work required. This would be less expensive than die casting. It assumes that you think you could get more business from the customer.

Die Casting could be warranted if one had a die casting machine and just needed a new die (permanent mold). Otherwise purchasing a die casting machine would not be warranted unless one had other business or you really thought you could “reel the customer in” for big $ future contracts.

Based on this analysis Lost Foam Casting, can be eliminated as a potential process. The work involved in creating each mold pattern, even if multiple patterns were possible would cost money and because both the mold and mold pattern is destroyed during each operation the work would have to be repeated. Finally, there is no guarantee that a foam pattern consisting of multiple parts would produce satisfactory multiple parts.

Based on this analysis Investment Casting, can be eliminated as a potential process. The work involved in creating each mold pattern and mold even though multiple patterns are possible would green sand casting (where one patten is prepared) a less expensive alternative. This is especially true given that a small amount of finish work is acceptable to the customer.

Final Answer

There are three casting processes which should be considered. These are in order of expense the following.

1. Green Sand Casting would be the least expensive option. No specialized equipment must be purchased as would be necessary for die casting. Creating a mold pattern for multiple parts would be less expensive than creating a permanent mold for multiple parts. The cost of destroying the mold is not likely to exceed that of creating a permanent mold or purchasing either a die or die casting machine. The contract is only for one year.

2. Permanent Mold Casting could be warranted if one wanted to impress the customer due to less finish work required. This would be less expensive than die casting. It assumes that you think you could get more business from the customer.

3. Die Casting could be warranted if one had a die casting machine and just needed a new die (permanent mold). Otherwise purchasing a die casting machine would not be warranted unless one had other business or you really thought you could "reel the customer in" for big $ future contracts.

Neither Lost Foam nor Investment Casting is appropriate for the following reasons.

- Lost Foam Casting: The work involved in creating each mold pattern, even if multiple patterns were possible would cost money and because both the mold and mold pattern is destroyed during each operation the work would have to be repeated. Finally, there is no guarantee that a foam pattern consisting of multiple parts would produce satisfactory multiple parts.

- Investment Casting: The work involved in creating each mold pattern and mold even though multiple patterns are possible would green sand casting (where one patten is prepared) a less expensive alternative. This is especially true given that a small amount of finish work is acceptable to the customer.

Both copper (Cu) and silver (Ag) are often cast. Which type of foundry would be more expensive to operate based solely on energy costs? By how much?

	Copper (Cu)	Silver (Ag)
Melting Point	1084ºC	962ºC
Heat of Fusion	2.85×10^{10} J/m^3	1.97×10^{10} J/m^3
Solid Heat Capacity	3.43×10^6 J/(m^{3}K)	3.43×10^6 J/(m^{3}K)
Liquid Heat Capacity	5.48×10^6 J/(m^{3}K)	2.88×10^6 J/(m^{3}K)

First one needs to determine an appropriate starting temperature (before the furnace is turned on) and an appropriate superheat (pouring temperature-melting temperature). These temperatures are 25ºC and 100ºC respectively. Second, one must assume equal volume so for purposes of the calculations the volume will be assumed to be 1m^3.

	Copper (Cu)	Silver (Ag)
Heat to Melting Temperature $\Delta H = VC_{PS}(T_M - T_0)$ Heat Required (Volume)(Heat Capacity of Solid)(Difference in Temperature between Melting T and Ambient)	$\Delta H = VC_{PS}(T_M - T_0)$ $(1m^3)\left(3.43\times10^6 \frac{J}{m^3C}\right)(1084C - 25C)$ $3.63\times10^9\ J$	$\Delta H = VC_{PS}(T_M - T_0)$ $(1m^3)\left(3.43\times10^6 \frac{J}{m^3C}\right)(962C - 25C)$ $3.21\times10^9\ J$
Melt $\Delta H = V\Delta H_F$ Heat Required (Heat of Fusion)(Volume)	$\Delta H = V\Delta H_F$ $(1m^3)\left(2.85\times10^{10} \frac{J}{m^3}\right)$ $2.85\times10^{10}\ J$	$\Delta H = V\Delta H_F$ $(1m^3)\left(1.97\times10^{10} \frac{J}{m^3}\right)$ $1.97\times10^{10}\ J$
Superheat Liquid $\Delta H = VC_{PL}(T - T_M)$ Heat Required (Volume)(Heat Capacity of Liquid)(SuperHeat)	$\Delta H = VC_{PL}(T - T_M)$ $(1m^3)\left(5.48\times10^6 \frac{J}{m^3C}\right)(100C)$ $5.48\times10^8\ J$	$\Delta H = VC_{PL}(T - T_M)$ $(1m^3)\left(2.88\times10^6 \frac{J}{m^3C}\right)(100C)$ $2.88\times10^8\ J$
Total	3.27×10^{10}J	2.32×10^{10}J

Thus it would cost 41% more to operate a copper foundry.