Solutions to Homework Number Three
Due Monday January 30, 2012

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.

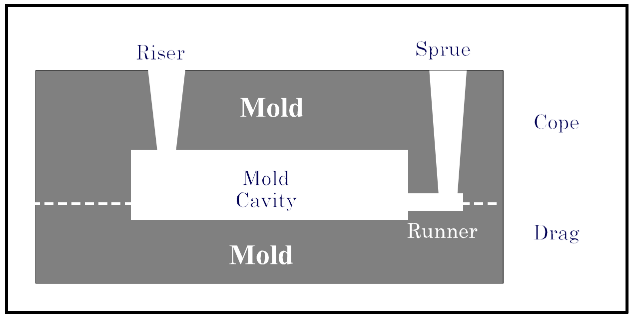

Figure 1: Green Sand Casting Mold

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: green sand, lost foam, and permanent mold.

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 green sand casting the mold cavity is made by packing green sand around a pattern. The pattern is removed and metal is poured into the mold. The mold is destroyed when the product is removed.

In lost foam casting a mold pattern is made of polystyrene or other foam. The mold pattern is placed in a container of loose sand. Metal is then poured into the mold. The mold pattern evaporates due to contact with the hot metal. This creates the mold cavity. The mold is destroyed when the product is removed.

In permanent mold casting molten metal is poured into a permanent mold. This means that the mold is not destroyed as is the case with both green sand and lost foam casting. The mold can be used repeatedly. However, as the mold is typically made of metal, this process can only be used with lower melting temperature materials.

3) Which casting process (of the ones discussed in class) would you use to make the following part.?

The part shown in the HW is requires an good surface finish and must be made to high tolerances The main consideration is how to make a mold cavity that will allow for the metal to flow in appropriately.

It would be difficult to use green sand casting for several reasons. The mold pattern would have to be made of a material that would never deform during processing. Multiple sprues and risers would be needed.

Lost foam or investment (lost wax) casting seems to be a viable option. It would be possible to carve the appropriate pattern in wax or polystyrene. However, because in the lost foam casting the molten metal evaporates the "foam" in its path, care must be taken with the holes.

Either permanent mold or die casting are the best possibility, it would ensure the quality of the mold cavity.

4) Copper is often cast. How much more expensive would it be to run a copper foundry require than an aluminum foundry. A melting temperature of 1085° C, a heat of fusion of $1.62 \times 10^9 J/m^3$. Solid copper has a heat capacity of $3.6 \times 10^6 J/m^3K$. Liquid copper has a heat capacity of $3.8 \times 10^6 J/m^3K$.

The primary cost would be energy. Therefore one needs to compare the energy of the two processes.

In order to cast metal is typically needs to be heated to 100°C above the melting temperature. This ensures it will flow and not solidify before filling the mold cavity. This means energy needs to be provided to do the following.

- Heat the solid metal from room temperature to the melting point
- Melt the metal
- Increase the temperature of the liquid metal by 100°C.

The energy required to heat the solid metal from room temperature to the melting point is,

$$\Delta H = VC_{PS}\left(T_M - T_0\right)$$

ΔH represents the heat required, V is the volume of metal being melted, C_{PS} is the heat capacity of the solid, T_M is the melting temperature, and T_0 is room temperature (25°C).

The energy required to melt the metal (at the melting temperature) is,

$$\Delta H = V\Delta H_F$$

ΔH_F is the heat of fusion of the material.

The energy required to heat the molten liquid is,

$$\Delta H = VC_{PL}\left(T - T_M\right)$$

C_{PL} is the heat capacity of the liquid, and T is the final temperature.

To compare the energy required for the two materials, one needs to assume that equal volumes of both will be made. Thus we can assume a volume of $1m^3$. We will also assume that we will heat both materials to 100°C above the melting point.

Consider the energy to melt aluminum.

The energy required to heat solid aluminum to its melting temperature is,

$$\Delta H = VC_{PS}\left(T_M - T_0\right)$$
$$\Delta H = \left(1m^3\right)\left(2.6\times 10^6 \frac{J}{m^3 K}\right)\left(660^o C - 25^o C\right) = 1.6\times 10^9 J$$

The energy required to melt aluminum at this temperature is,

$$\Delta H = V\Delta H_F = \left(1m^3\right)\left(9.5\times 10^8 \frac{J}{m^3}\right) = 9.5\times 10^8 J$$

The energy required to raise the temperature of molten aluminum by 100°C is,

$$\Delta H = VC_{PL}\left(T - T_M\right)$$
$$\Delta H = \left(1m^3\right)\left(3.0\times 10^6 \frac{J}{m^3 K}\right)\left(100^o C\right) = 3.0\times 10^8 J$$

The total amount of energy required to heat the aluminum from room temperature to 100°C above the melting point is: $2.85\text{x}10^9$J.

Consider the energy to melt copper.

The energy required to heat solid copper to its melting temperature is,

$$\Delta H = VC_{PS}\left(T_M - T_0\right)$$
$$\Delta H = \left(1m^3\right)\left(3.6\times 10^6 \frac{J}{m^3 K}\right)\left(1085^o C - 25^o C\right) = 3.8\times 10^9 J$$

The energy required to melt copper at this temperature is,

$$\Delta H = V\Delta H_F = (1m^3)\left(1.62\times 10^9 \frac{J}{m^3}\right) = 1.62\times 10^9 J$$

The energy required to raise the temperature of molten copper by 100°C is,

$$\Delta H = VC_{PL}(T - T_M)$$

$$\Delta H = (1m^3)\left(3.8\times 10^6 \frac{J}{m^3 K}\right)(100^o C) = 3.8\times 10^8 J$$

The total amount of energy required to heat the copper from room temperature to 100°C above the melting point is: $5.8\text{x}10^9$J.

It therefore takes twice as much energy to process copper.