2.810 Fall 2013

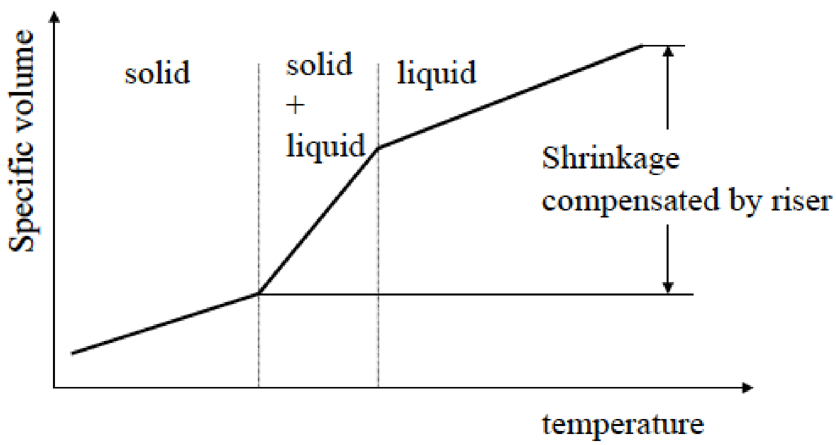
Casting Homework Solution

Problem 1a

The defects and discontinuities occur because the thinner sections of the casting solidify faster. As a result, the thick sections will contract more than the thin sections will allow. Hence this could lead to residual tension stresses, fracture, shrinkage, voids and porosity.

Problem 1b

The graph of specific volume vs. temperature for an alloy metal is given below, including compensation for shrinkages.



Problem 2

The observed shrinkages are all within the usual range for aluminum (0.013/1). The cause for deviations lies within the cooling pattern, the mold material, measurement accuracy, and the placement of gates and riser. Generally green sand molds are less stiff than their no-bake counterparts, which are solidified by using a binding component. However, the data does not show that the dimensions, which are expected to be constrained, experience less shrinkage for the no bake, in fact it is the other way around. Note instead, that not all of the variations for the green sand mold are easily explained. Some possible comments for the green sand mold are:

- the height E exhibits a considerably higher shrinkage, since the material is allowed to contract freely
- less shrinkage in the area of the gate and the riser, since these sections solidify last and material is continuously fed into the mold,

Problem 3

a. From the lumped parameter model for die casting

$$t = \frac{w\rho C}{2h} 1n\left[\frac{T_{inject} + \Delta T_{sp} - T_{mold}}{T_{eject} - T_{mold}}\right]$$

Note the film coefficient can vary for aluminum die casting from about 1 – 14kW/m^{2}C depending upon the surface condition. Here we use h = 1.58kW/m^{2o}C.

For w = 2.5

$$t = \frac{2.5\times10^{-3}[m]\times 6.6\times10^{3}[kg/m^{3}]\times 0.419[kJ/kg\circ C]}{2\times1.58[kW/m^{2}\circ C]}\ln\left[\frac{410+270-60}{240-60}\right] = 2.7\sec$$

For w = 8
T = 2.7*8/2.5=8.6

Note here we have assumed that “C channel” shapes look like thin sheets. Probably these shapes would not cool as quickly in the corners and on the inside.

We can compare these values with the die casting cooling time approximations given in the Cast lecture slides. For zinc the estimate is $t \cong 0.42\sec/mm\times W_{\max}$, where W_{max} is the max. thickness. This gives 1.05sec for the 2.5 mm part thickness, and 3.36 sec for the 8 mm part. Apparently the approximations use a larger value for h of about 4.04kW/m^{2o}C.

b. The solution given in the class notes and derived by Flemings is for solidifications only. This resulted in the time estimate t = C(V/A)^2 which is called Chvorinov’s Rule. (these values are determined experimentally, and – see separate handout- range C ~ 2 to 4 min/cm^2). Recall that during solidification it is assumed that the part is at a constant temperature T_{melt}. In reality the part is poured at some initial temperature $T_i > T_{melt}$ and it is removed at some temperature $T_r < T_{melt}$. Hence the complete time for cooling would be the time to go from T_i to T_r (ignoring the latent heat of fusion for the moment) and then add to that the solidification time from Chvorinov’s Rule (which only accounts for the latent heat of fusion). For a rough estimate of the cooling time we could use a lumped parameter model like the one shown in class for die casting.

$$mC \cdot \frac{dT}{dt} = \dot{q}$$

Where *mC* is for the metal part and RHS is the rate of heat transfer out of the part. To solve this problem we would need to solve for the temperature gradient in the sand but now with a changing temperature at the wall equal to the current temperature of the cooling part. Here we are ignoring any temperature gradient in the part, any film coefficient and the fact that the mold is actually finite in extent.