Massachusetts Institute of Technology
2.008: Design and Manufacturing II

Problem Set 2 Solutions

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Problem 1-1. Injection Molding

The gate and runner system that you use to move plastic into an injection molding cavity are critical design parameters. Suppose the polymer material that you are using has a viscosity μ of $950Ns/m^2$ under your processing conditions. Suppose your initial gate and round runner system is 3.5 mm in diameter and approximately 25 mm long. Your part has a volume of approximately 20000 mm^3 and a projected area of approximately 1800 mm^2. Your Engel machine claims that it can melt and deliver material at a rate of 165 cm^3/sec. Assume that there is no pressure loss bewteen the mold cavity and the runner system, and none of the clamping force is lost in deforming the molds when they come together.

(a) What is shortest injection time for the part?

The injection time is bounded by the delivery rate of the Engels machine. The shortest time is therefore $\frac{20000}{160*1000} = 0.121$ *seconds.*

(b) Recall that the equation for Newtonian flow through a round channel is:

$$Q = \frac{\pi P r^4}{8\mu L}$$

where Q is the flow (m^3/s), P is the pressure change (Pa), r is the radius of the channel (m), μ is viscosity (Ns/m^2), and L is the length of the channel (m).

What is the pressure required to inject your part if you use the smallest injection time?

Using the smallest injection time, the flow would have to be $0.000165m^3/s$*. Therefore, the pressue would be* $P = \frac{0.000165*8*950*0.025}{\pi(0.00175^4)} = 1.064 * 10^9 Pa = 154346$ *psi . This is not a reasonable pressure for any standard machine.*

(c) What happens if you change the injection time to 1 second instead? What is the pressure required? What is the required clamping force? What happens to the clamping force if you make your channel radius 10 percent larger?

If we change the injection time to 1 second, the flow rate would be $Q = 2 * 10^{-5} m^3/s$*. Therefore, the required pressure would be* $P = \frac{2*10^{-5}*8*950*0.025}{\pi(0.00175^4)} = 1.28 * 10^8$ *Pa* $= 18708$ *psi which is more reasonable. The clamping force would be* $18708*1800/(25.4)^2 = 26.09$*tons which is quite reasonable. Making the radius 10 percent larger essentially decreases the pressure by a factor of* $1.1^4 = 1.464$*. Therefore, the new clamping force would be* 17.81 *tons.*

(d) Why is it ok to increase the injection time to 1 second? What prevents you from using a 10 second injection time? What are the disadvantages of making a 10mm radius runner channel?

Increasing the injection time by less than one second is ok since it is the cooling time for this part which dominates the cycle time. In addition, it makes it feasible to produce this part under normal *pressures. If the injection time is 10 seconds, the plastic in the runner channels would begin to harden before all of the plastic is injected into the mold. The parts would become short shots.*

Using a 10 mm radius runner channel results in a cycle time for the part that is dominated by the time it takes for the 20mm of plastic in the runners to cool. The runner and gate plastic must harden before the clamps can open because the gates are actually broken off at this point. The actual ammount of extra plastic used in the runner is not an issue because it can be recycled and plastic is quite cheap.

Problem 1-2. Geometry

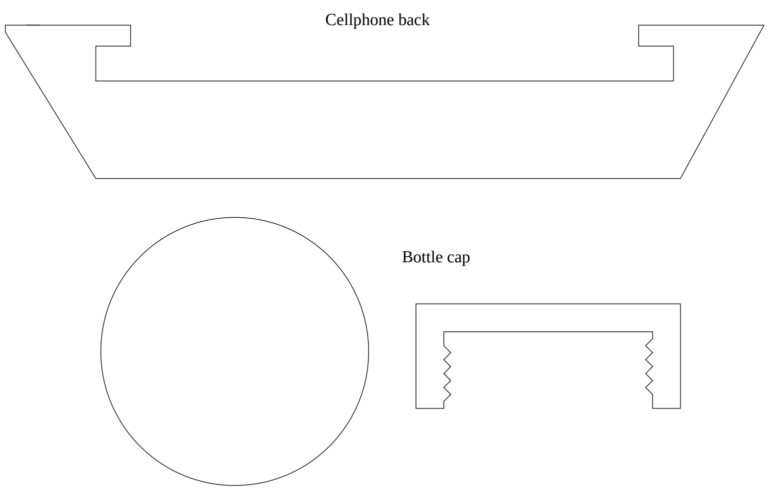

Figure 1: Geometry problem

The top part in Figure 1 is used as the battery cover in a cellphone. How would you modify the design to make it easier to manufacture?

Add a radius to each corner; make the part uniform thickness, remove the undercuts.

Plastic bottle caps [the kind that screw on to a bottle] illustrate one major injection molding hurdle. What is it? How can you get around it?

The threads on the bottle cap are all undercuts. After the plastic hardens, it holds the cap on. The problem is removing the cap from the mold. It can be screwed off, which is time consuming, or it can be popped off before the plastic in the threads fully hardens.

Problem 1-3. The elements What happens to a plastic part that is left outside in the sun for several years? The absorption spectrum for carbon black is presented below (Figure 2). Why might you want to add carbon black to a plastic part that is meant for outdoor use?

The UV in sunlight degrades the polymer, and the plastic becomes dry and brittle. Carbon black can be added to the plastic in order to help absorb most of the harmful UV light. It will however, also increase the temperature of the part [which is bad for the plastic used in the interior of your Jeep].

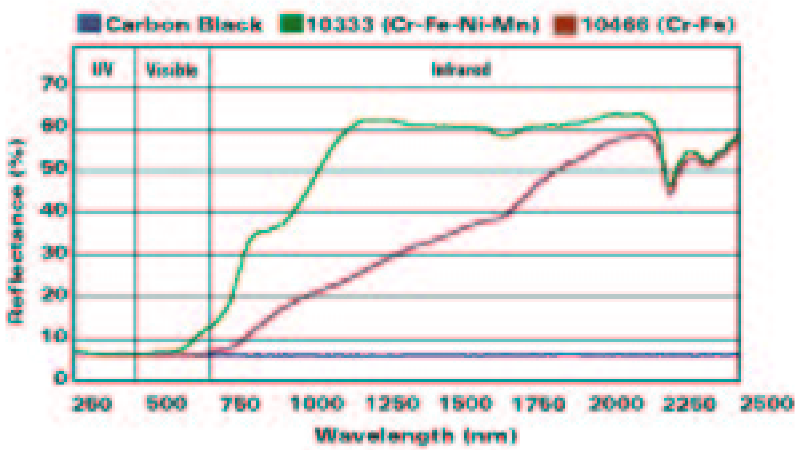

Figure 2: Spectrum of carbon black