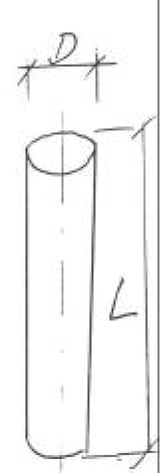
2.810 Injection Molding 1/11

HW #6 - Solutions



Problem 1.) a) $T_{mold} = 30°C$ $D = 2cm$

$T_{wax} = 100°C$ $L > D$

$T_{final} \approx 37°C$

$$\theta = \frac{T - T_\infty}{T_i - T_\infty} = \frac{(37-30)°C}{(100-30)°C} = \frac{1}{10}$$

For constant temp. mold $Bi^{-1} = \frac{k}{\bar{h} r_0} = 0$

$\frac{r}{r_0} = 0$ @ centerline

From Fig. 5.8 in „Transient Conduction" handout: $F_0 \approx 0.5$ for a cylinder

$$F_0 = \frac{\alpha t}{r_0^2}$$

$$0.5 = \frac{(10^{-3}\ cm^2/s)\, t}{(1cm)^2}$$

$$\Rightarrow t = 500\,s$$

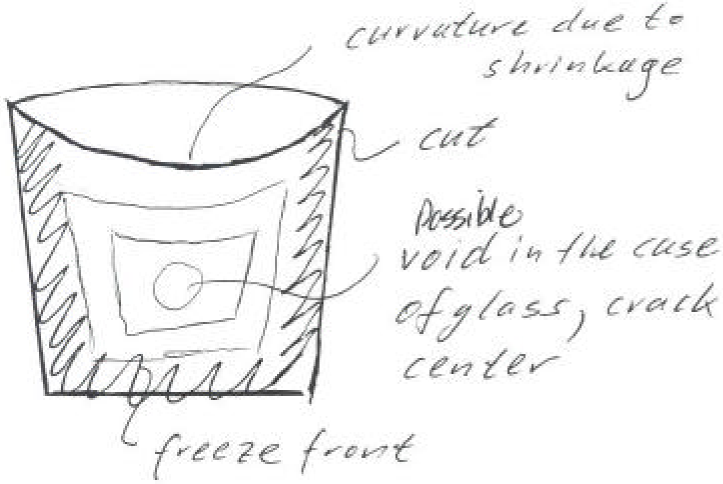
If L and D were of the same order then the heat loss to the mold thru the bottom surface would become significant relative to the heat loss thru the sides. Cooling time would be reduced.

cont'd

2.810 Injection Molding
HW #6 - Solutions

Problem #1) cont'

b) Solidified Candle w/ $L = 0$



Wax next to walls solidifies first. Wax in center cools and shrinks causing a depression. Finally case of "hydrostatic tension" may occur in very center which is last to solidify and is constrained by neighbooring already solidified material.

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Problem 2.)

1) Cooling Time

Max. wall thickness: $D = 0.16\,cm$

$$\Rightarrow D/2 = L = 0.08\,cm$$

from handout $t_{cool} \approx \frac{L^2}{\alpha}$

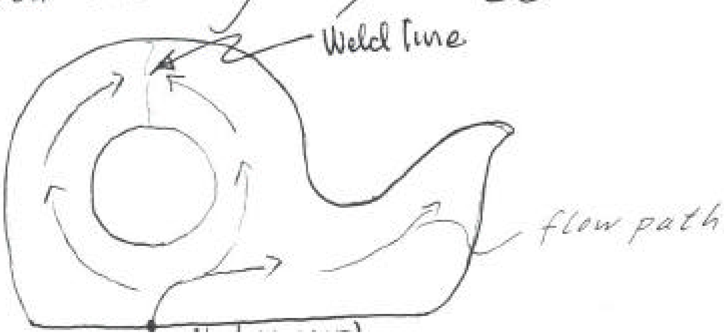
with $\alpha \approx 10^{-3}\,cm^2/s$ diffusivity for polymers

$$\Rightarrow \underline{t_{cool} = 6.4\,s}$$

2) Special Features

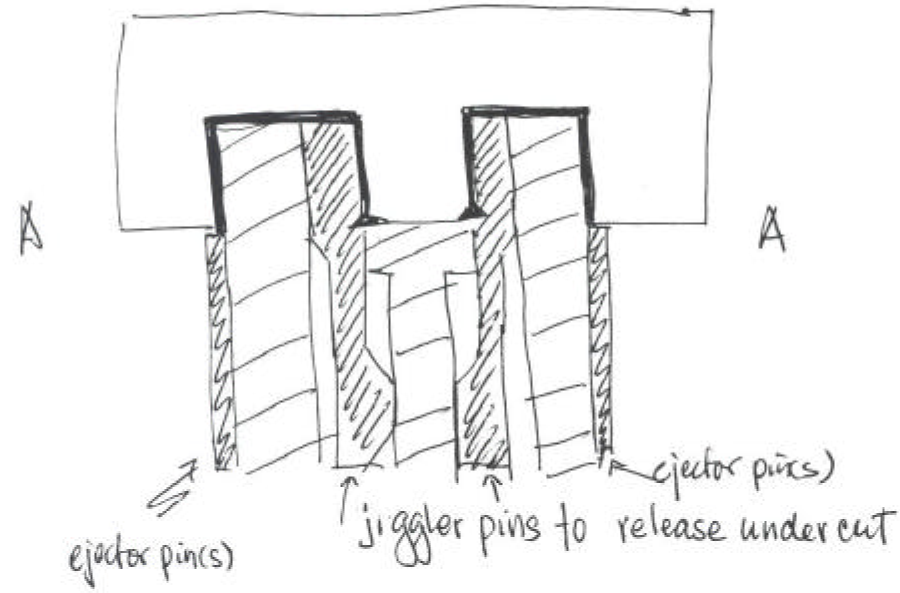
- 2 undercuts require special tool features
- serrated edge requires side pull
- ejector pins to remove part (see attached drawing)

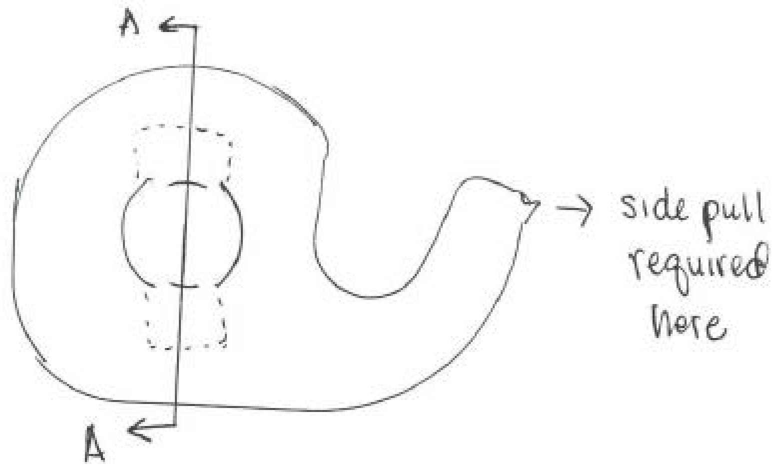
3) Mold Filling Sequence



cont'

Some features of the tooling for the plastic tape dispenser





2.810 - Injection Molding
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Problem 2) cont'

4) Machine Requirements

Clamp Force: $F = p \cdot A_{proj} \cdot n_{cavity}$

injection pressure: $p \approx 10{,}000$ psi

projected area: $A \approx 2.5 \times 2.5 \text{ in}^2 = 6.25 \text{ in}^2$

number of cavities: $n_{cav} = 4$ (assume here)

$\Rightarrow F = 250{,}000 \text{ lb} \mathrel{\hat{=}} 125 \text{ tons}$

(Note: conservative estimate, large area includes runner, 10ksi probably on high side see Boothroyd, Dewhurst & Knight p.332 in handout)

Shot Size

wt/part = 0.5 oz $\Rightarrow$ 4 cavities $\Rightarrow$ 2.0 oz.wt

2.0 oz wt. · 28 oz/g = 56 g

$56 \text{ g} / 1.3 \text{ g/cm}^3 = \underline{43.1 \text{ cm}^3} \mathrel{\hat{=}} \underline{1.43 \text{ oz.fl}}$

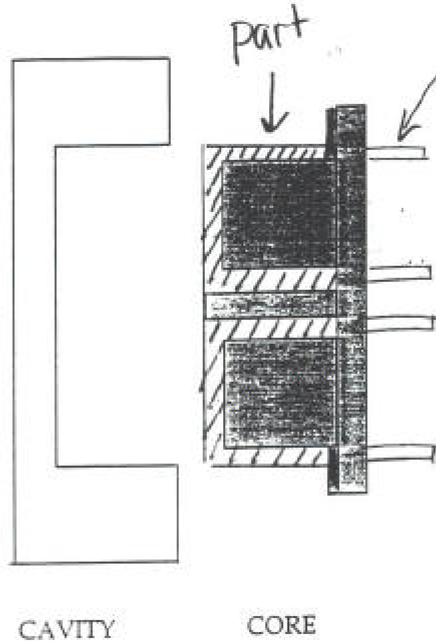
A shot size of at least 1.43 oz.fl. is required ~~to~~ injection mold 4 parts at once. Note: LMP Machine: 1.5 oz.

Note that runner system may add something like 37% for a 16 cm^3 part - our parts ar 14 cm^3 each. See Table 8.2 in Boothroyd Dewhurst & Knight handouts.

Injection Molding Homework Sol'n

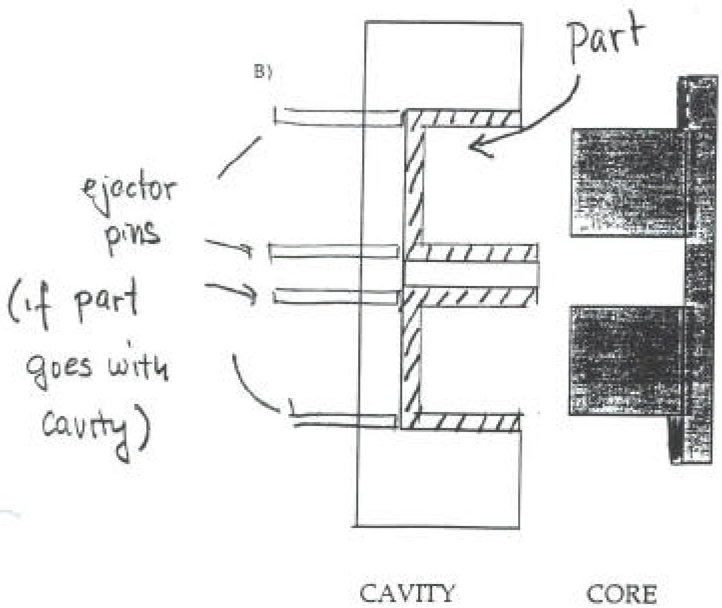
#3 a, c & d

A)



Here part will go with core. Ejectors in core needed to strip part. Hence nozzle from cavity side

B)



Here part might go with core or cavity. If it goes with cavity then nozzle would be from the core side and ejectors from cavity would leave mark on outside of part. Probably best if part goes with core. This can be adjusted by draft angle, mold surface, gate and molding cycle.

Injection Molding Homework Solution HW #6

Problem #3) b)

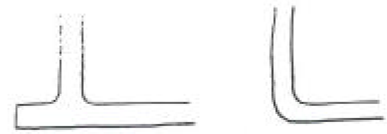
Design Alterations / DFM

a.) Add draft angle

b.) Round corners

c.) Make walls same thickness

d.) Eliminate "overhang" if possible



Estimate Part Cycle Time:

$$t \cong \frac{H^2}{\alpha} = \frac{\left(0.635\,\mathrm{cm}/2\right)^2}{\left(10^{-3}\ \mathrm{cm}^2/\mathrm{sec}\right)} = 101\ \mathrm{sec}.$$

(This time is too long, so redesign with thinner walls and ribs if necessary to stiffen.)

Clamping Force (not asked for, but here it is)

Projected area $\cong (4.50 + 0.50) \times (3.50 + 0.50)$

$\cong 20\ \mathrm{in}^2$ + runner

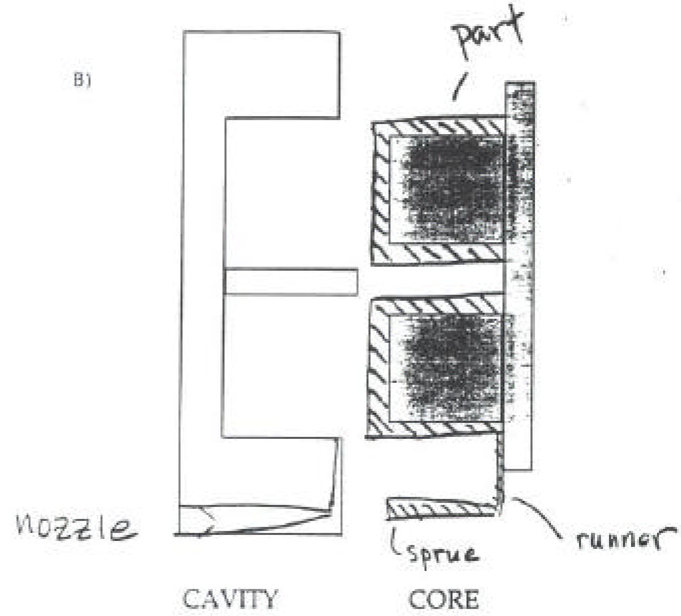
eliminate in redesign

Pressure $\cong$ 7000 psi

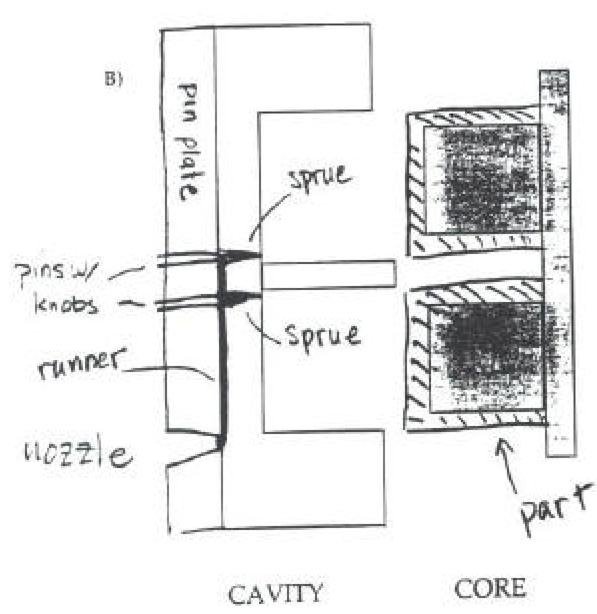
Clamp force $\cong 20\ \mathrm{in}^2 \times 7000\ \frac{\mathrm{lb}}{\mathrm{in}^2} = 140{,}000\ \mathrm{lbs}$

$= 70$ tons

3e)


B)
part
nozzle
sprue
runner
CAVITY
CORE

3f


B)
pin plate
sprue
pins w/
knobs
sprue
runner
nozzle
part
CAVITY
CORE

#4 Consider transport rate / cooling rate (units $\frac{1}{\text{time}}$)

for injection molding

transport $\frac{1}{t} \sim \frac{V}{L_x}$

$\longrightarrow \frac{1}{4} \frac{V L_z}{\alpha} \cdot \frac{L_z}{L_x}$

cooling $\frac{1}{t} \sim \frac{\alpha}{(L_z/2)^2}$

typical values are $\frac{1}{4} \dfrac{10\frac{cm}{s} \times 0.1\,cm}{10^{-3} \frac{cm^2}{s}} \times \dfrac{0.1\,cm}{10\,cm}$

$\cong 2.5$

hence the two rates are about equal within one order of magnitude.

for die casting typical values are

$$\frac{1}{4}\;\frac{10\,\frac{cm}{s}\times 0.1\,cm}{.3\,\frac{cm^2}{s}}\times\frac{0.1}{10}=10^{-2}$$

Hence the heat transfer rate is much faster and there is the danger of a thin runner system from solidifying before the molds are filled. (Note that the actual situation is a little better than this because the heat transfer rate is smaller due to film resistance)

Note that the multicavity tool for die casting shown in Fig 4 does not show overflow wel commonly use. See p.413 handout Design for Die Cas

5) eq'n 8.5 in Boothroyd et al is

$$t_c = \frac{h^2_{max}}{\pi^2 \alpha} \ln \frac{4(T_i - T_m)}{\pi (T_x - T_m)}$$

let $\frac{T_x - T_m}{T_i - T_m} = 0.1$

$$t_c = \frac{h^2_{max}}{4\alpha} \times \frac{4}{\pi^2} \ln \frac{40}{\pi}$$

$$= 1.03 \times \frac{(h_{max}/2)^2}{\alpha}$$