Injection Molding
BALANCING RUNNER SYSTEMS

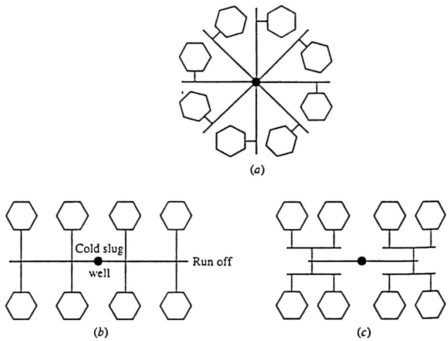


Figure 1: Two naturally balanced (symmetric) runner systems and one counter-example.

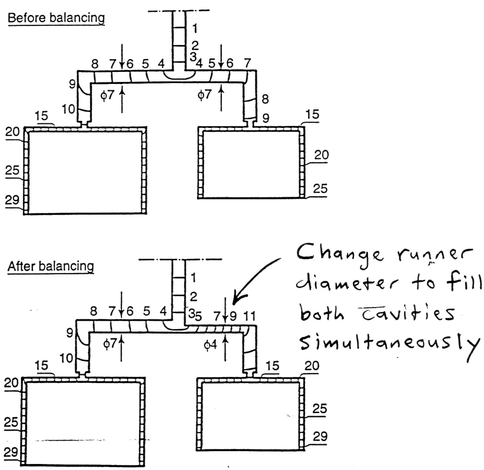


Figure 2: An artificially balanced runner system.

Injection Molding
CONSEQUENCE OF IMBALANCED RUNNER SYSTEMS

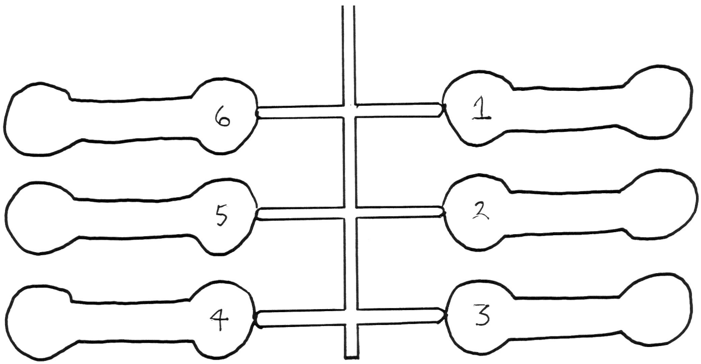


Figure 3: Need to **overpack** 1 and 6 to fill 3 and 4.

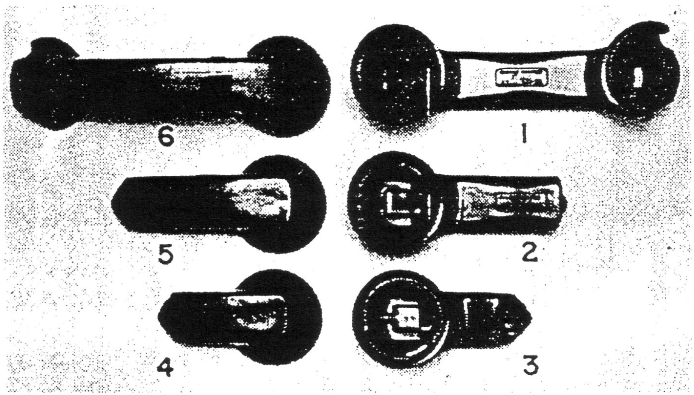


Figure 4: Short shots in a telephone-handle molding die.

Injection Molding
INCOMPRESSIBLE CONTINUITY EQUATION FOR LIQUIDS

Cartesian coordinates: x, y, z

$$\frac{dV_x}{dx} + \frac{dV_y}{dy} + \frac{dV_z}{dz} = 0$$

Cylindrical coordinates: r, θ, z

$$\frac{1}{r}\frac{d}{dr}(rv_r) + \frac{1}{r}\frac{dv_\theta}{d\theta} + \frac{dv_z}{dz} = 0$$

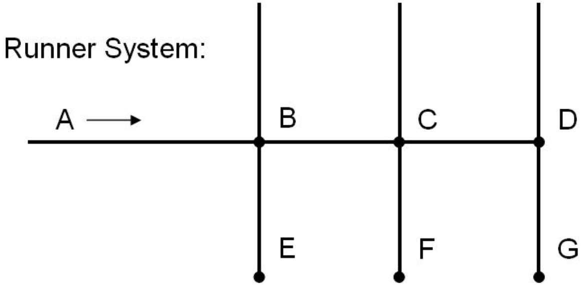
Spherical coordinates: r, θ, ϕ

$$\frac{1}{r^2}\frac{d}{dr}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{d}{d\theta}(v_\theta \sin\theta) + \frac{1}{r\sin\theta}\frac{dv_\phi}{d\phi} = 0$$

All are simply $\vec{\nabla} \cdot \vec{v} = 0$

Injection Molding

Example: use Hagen-Poiseuille Law to balance the runners



$$\text{Hagen-Poiseuille Law: } \Delta P = \frac{8\mu L Q}{\pi R^4}$$

Suppose: $R_{AB} = R_{BC} = R_{CD} = R_{DG} \equiv R$

What size do we make R_{BE} and R_{CF} to balance the pressures at E, F and G?

$$\text{Flow is split 6 ways:} \qquad Q_{AB} \equiv Q$$

$$Q_{BC} = \frac{2}{3}Q$$

$$Q_{CD} = \frac{1}{3}Q$$

$$Q_{BE} = Q_{CF} = Q_{DG} = \frac{1}{6}Q$$

All lengths are equal, define $K \equiv 8\mu L/\pi$

Injection Molding

Pressure drops are additive:

$$\begin{aligned}\Delta P_{BG} &= \frac{KQ_{BC}}{R_{BC}^4} + \frac{KQ_{CD}}{R_{CD}^4} + \frac{KQ_{DG}}{R_{DG}^4} \\ &= \frac{2KQ}{3R^4} + \frac{KQ}{3R^4} + \frac{KQ}{6R^4} \\ &= \frac{7KQ}{6R^4}\end{aligned}$$

$$\begin{aligned}\Delta P_{BF} &= \frac{KQ_{BC}}{R_{BC}^4} + \frac{KQ_{CF}}{R_{CF}^4} \\ &= \frac{2}{3}\frac{KQ}{R^4} + \frac{KQ}{6R_{CF}^4}\end{aligned}$$

$$\text{First Result: } \Delta P_{BG} = \Delta P_{BF} \quad \Rightarrow \quad \frac{1}{6R_{CF}^4} = \frac{1}{2R^4}$$

$$R_{CF} = \frac{R}{3^{1/4}} = 0.76R$$

$$\Delta P_{BE} = \frac{KQ}{6R_{BE}^4}$$

$$\text{Second Result: } \Delta P_{BE} = \Delta P_{BG} \quad \Rightarrow \quad \frac{1}{6R_{BE}^4} = \frac{7}{6R^4}$$

$$R_{BE} = \frac{R}{7^{1/4}} = 0.61R$$

Injection Molding
EXTREME EXAMPLE OF RUNNER BALANCING

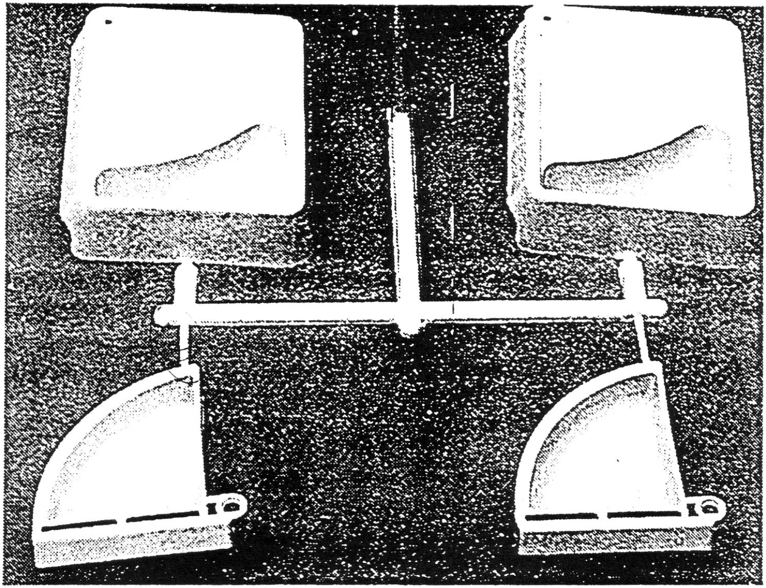
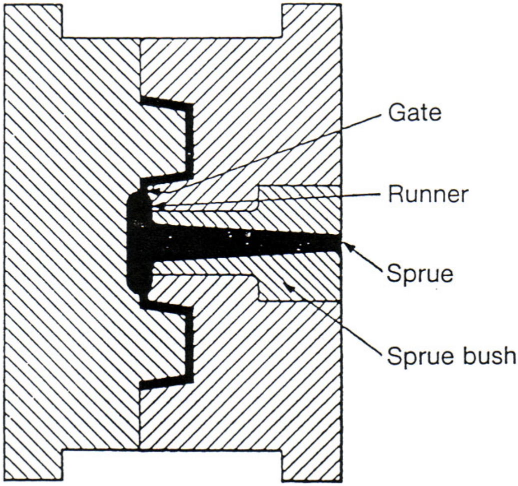


Figure 5: Family mold (pair of dishwasher detergent holding set).

Injection Molding
CONVENTIONAL INJECTION MOLDING



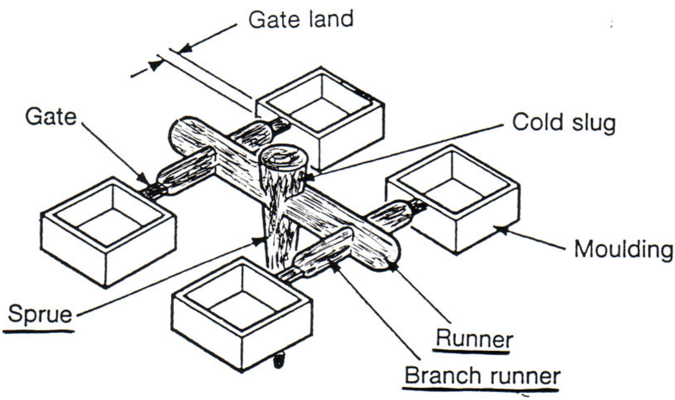


Figure 6: Discard or regrind.

Injection Molding
INJECTION MOLDING DEFECTS

Weld lines

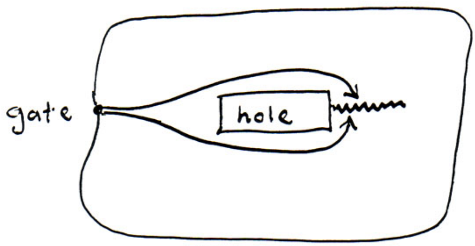


Figure 7: Cold flow fronts recombine to make a visible line that can be mechanically weak.

Voids, **Sink Marks**, **Shrinkage**

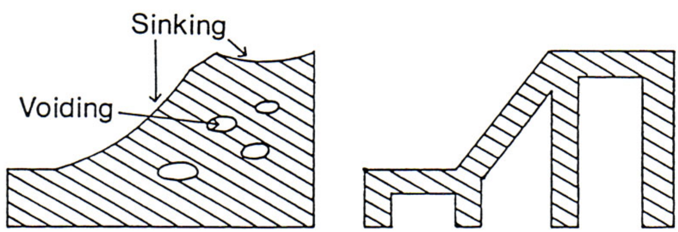


Figure 8: Use of ribs instead of a solid section. Solid section (left) and thin section (right). 10% shrink can be expected.

Thick sections cool after gate freezes.

Sticking - Injection pressure too high (overpack).

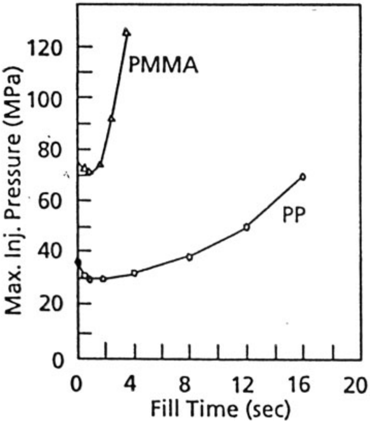
Warping - Insufficient cooling before ejection.

Burning - Extrusion temperature too high. Shear heating.

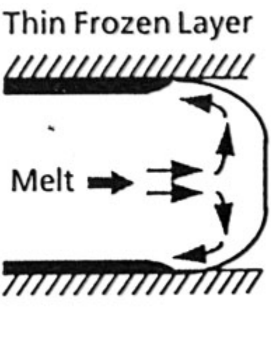
Injection Molding

MATERIAL AND INJECTION PRESSURE

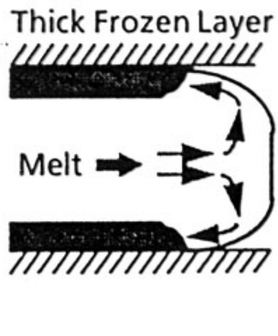
- Different materials require different injection pressures
- Different materials exhibit a wide range of viscosity levels



FROZEN LAYER IN FOUNTAIN FLOW

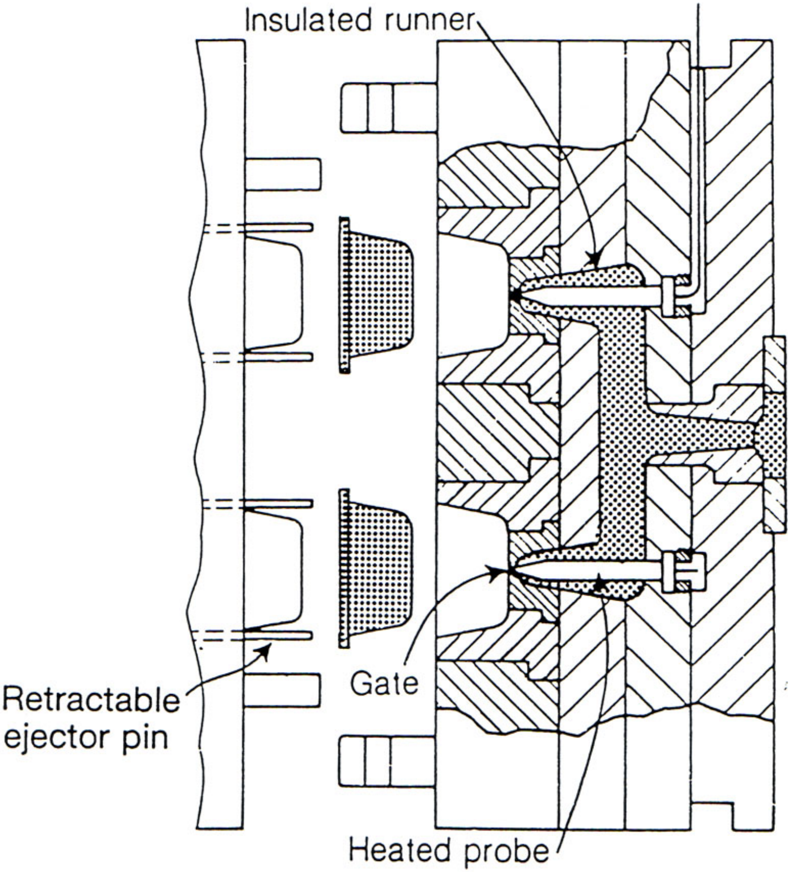


Fast Fill Time
Hot Mold Temp.
High Melt Temp.



Slow Fill Time
Cold Mold Temp.
Low Melt Temp.

Injection Molding
HOT-RUNNER SYSTEMS



More expensive mold
Potential degradation problems
Eliminates regrind
Automatic detachment