Injection Molding
BALANCING RUNNER SYSTEMS

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

Figure 2: An artificially balanced runner system.
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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.
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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: $r, \theta, z$

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

Spherical coordinates: $r, \theta, \phi$

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

All are simply $\nabla \cdot \vec{v} = 0$
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Example: use Hagen-Poiseuille Law to balance the runners

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 \( G \)?

Flow is split 6 ways: \( Q_{AB} \equiv Q \)

\[
Q_{BC} = \frac{2}{3} Q
\]

\[
Q_{CD} = \frac{1}{3} Q
\]

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

All lengths are equal, define \( K \equiv 8\mu L/\pi \)
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Pressure drops are additive:

\[
\Delta P_{BG} = \frac{KQ_{BC}}{R_{BC}^4} + \frac{KQ_{CD}}{R_{CD}^4} + \frac{KQ_{DG}}{R_{DG}^4}
= \frac{2KQ}{3R^4} + \frac{KQ}{3R^4} + \frac{KQ}{6R^4}
= \frac{7KQ}{6R^4}
\]

\[
\Delta P_{BF} = \frac{KQ_{BC}}{R_{BC}^4} + \frac{KQ_{CF}}{R_{CF}^4}
= \frac{2KQ}{3R^4} + \frac{KQ}{6R_{CF}^4}
\]

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

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

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

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

\( R_{BE} = \frac{R}{7^{1/4}} = 0.61R \)
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EXTREME EXAMPLE OF RUNNER BALANCING

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

Figure 6: Discard or regrind.
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INJECTION MOLDING DEFECTS

Weld lines

![Gate and Hole Diagram](image)

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

Voids, Sink Marks, Shrinkage

![Sinking and Voiding Diagrams](image)

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

Thin Frozen Layer
Melt

Fast Fill Time
Hot Mold Temp.
High Melt Temp.

Thick Frozen Layer
Melt

Slow Fill Time
Cold Mold Temp.
Low Melt Temp.
Injection Molding
HOT-RUNNER SYSTEMS

More expensive mold
Potential degradation problems
Eliminates regrind
Automatic detachment