

Solidification of Metal Cheat Sheet

Chvorinov's rule, shrinkage, cast zones, dendrites

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Chvorinov's rule	$t = C (V / A)^n, n \approx 2$	V volume, A surface area, C mold constant; the equation is an image in the article
Riser rule	$(V/A)_{\text{riser}} > (V/A)_{\text{casting}}$	So the riser solidifies last
Cube example	$V/A = a / 6$	Mine: 100 mm cube gives 16.7 mm
Sphere example	$V/A = r / 3$	Mine: higher V/A freezes slower
Zones	Chill, columnar, equiaxed	Mold wall to center
Types	Progressive, directional, simultaneous	How the freezing front advances

Key takeaways

- Solidification is nucleation then grain growth; latent heat must leave and solute is redistributed in alloys.
- Fluidity (spiral test length) depends on mold design and material, superheat, pouring rate and chills.
- Turbulent pouring erodes the mold and traps gas, causing porosity; aim for laminar flow.
- Shrinkage because most solids are denser than liquid; graphitization in high-carbon cast iron offsets it.
- Pure metals and eutectics freeze at a constant temperature; other alloys freeze over a range and form dendrites.
- Break up dendrites by vibration, centrifuging, forced flow, rheocasting or squeeze casting.
- Rapid solidification: finer grains and porosity, better strength, fatigue and ductility.

Cast structure zones

Zone	Grains	Forms by
Chill	Small, random, equiaxed	Rapid nucleation at cold wall
Columnar	Elongated along heat flow	Favorably oriented grains keep growing
Equiaxed	Uniform, central	Heterogeneous nucleation in the melt