Casting: Pour molten material → mold → solidify → near-net-shape } create complex shapes w/ high dimensional accuracy

Material Removal: Subtracts material to achieve final form

Deformation: Bending, stretching, & twisting; no removal of material

Consolidation: Powdered / small particles → fusing → solid form

Casting Mastery Steps

Mold Making: sand / ceramic / metal
Melting: metal heated to M.P. → molten
Pouring: molten metal → mold
Solidification: metal cools & takes mold's form
Mold Removal: reveal solidified part
Finishing Touches: cleaning, polishing, & inspection

Advantages of Molding

Complex Shapes: geometries & internal cavities
High-Dimensional Accuracy: tight tolerances & consistency
Material Options: aluminum ~ steel; diverse ENGR needs
Cost-Effectiveness: repetitive parts ✓, minimal waste

Disadvantages of Molding

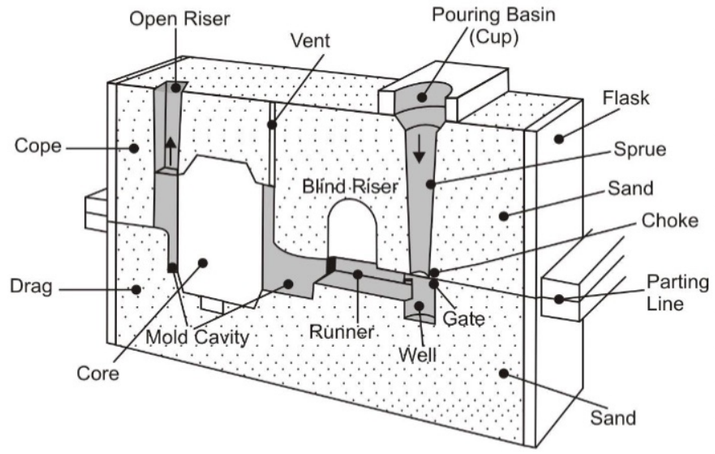
Surface Finish: rougher vs machining / forging / steps ↑
Strength Limitations: internal porosities / strength ↓ vs wrought forms
Dimensional Tolerances: tight tol. ≅ ↑ cost
Design Constraints: mold designs can limit geometries vs other shaping processes.
Safety Problems + Environmental Problems

Casting Terminologies

Pattern: master template defining casting shape
Molding Material: sand, ceramic, or metal
Flask: rigid frame holding molding material
Cope & Drag: top (cope) & bottom (drag) of flask
Core: inserts placed within mold to create cavities
Mold Cavity: empty space within mold; defines final casting shape
Riser: open (exposed to air) & blind riser; reservoir of molten metal feeding casting during solidification, compensating for shrinkage.
Gating System: channels guiding molten metal; pouring cup → cavity
Pouring Cup: entry point for molten metal into the gating system
Sprue: main vertical channel in gating channel
Runners: horizontal channels dist. molten metal to diff. mold parts
Gates: final channels connecting runners to mold cavity
Parting Line: seam where cope & drag meet
Draft: slight taper on mold walls / easy removal of casting
Casting: final solidified form

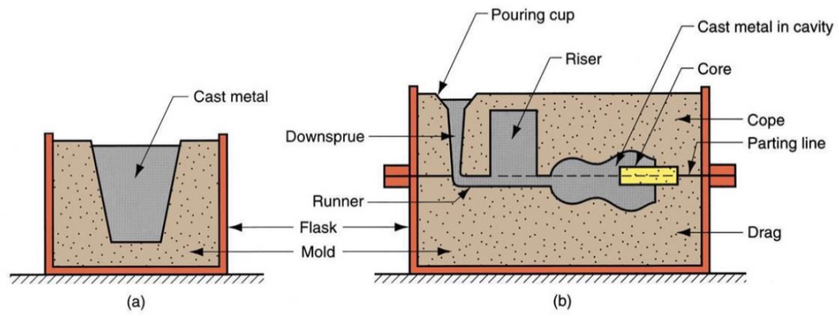
Role of the Mold

→ defines final shape / surface finishes / solid. process
→ mold material depends on casting complexity / surface finish / production vol.
→ successful mold: desired shape, minimizes defects, & efficient metal flow.



(a) **Open Mold**: container in the shape of desired part
→ simple design / low production volumes
→ e.g. sand casting, investment casting (burnout stage)

(b) **Closed Mold**: mold geometry is more complex & requires gating system (passageway) leading into the cavity
→ higher P: denser casting & finer surface finishes
→ complex shapes & high production volumes
→ e.g. Die casting & pressure casting



Expandable & Permanent Mold Processes

Expandable:
- mold destroyed after each casting cycle
- low ~ medium production volumes
- e.g. sand / investment / plaster mold casting
- Pros: ↑ flexibility for shape changes, ↓ initial costs
- Cons: ↑ per-unit cost, dimensional accuracy ↓ w/ each use

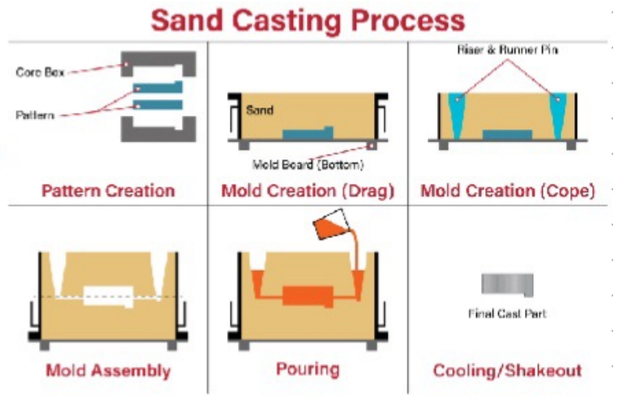
Permanent:
- mold reused for multiple cycles
- high production volumes of identical parts
- e.g. die / pressure / centrifugal casting
- ↑ production rates & dimen. accuracy, ↓ long term cost.
- ↑ initial mold cost, flexibility ↓.

Types of Casting Processes

Sand Casting (The Classic Canvas)

Pros:
- highly adaptable for diverse shapes & sizes,
- cost-effective for low~medium production vol.,
- excellent for creating internal cavities w/ cores

Cons:
- lower dimen. accuracy vs perm. molds, rougher finishes / need machining, mold destroyed w/ each use

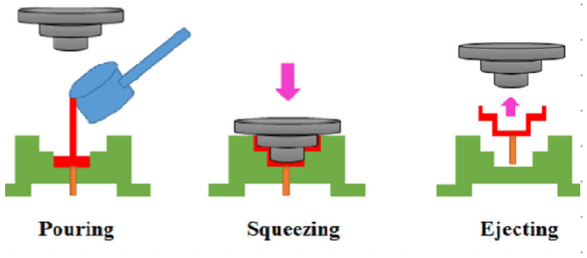


Squeeze Casting (Squeeze Casting)

applies external pressure to mold during solidification

Pros:
- superior dimen. accuracy & finish vs other methods,
- enhanced mechnical props. / pressure-induced solid.,
- high-strength & wear-resistant applications.

Cons:
- specialized equip. & mold design needed,
- limited to specific shapes compatible w/ this method.

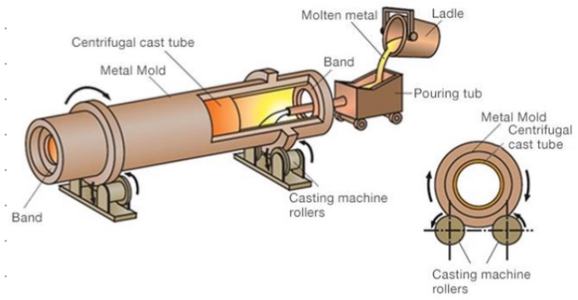


Centrifugal Casting

spins molten metal into cylindrical shapes w/ exceptional density & uniformity

Pros:
- strong homogeneous cylindrical shapes,
- minimize internal defects / gas porosity
- high production vol. for repetitive parts

Cons:
- cylindrical geometries only, specialized equip. & mold design needed.

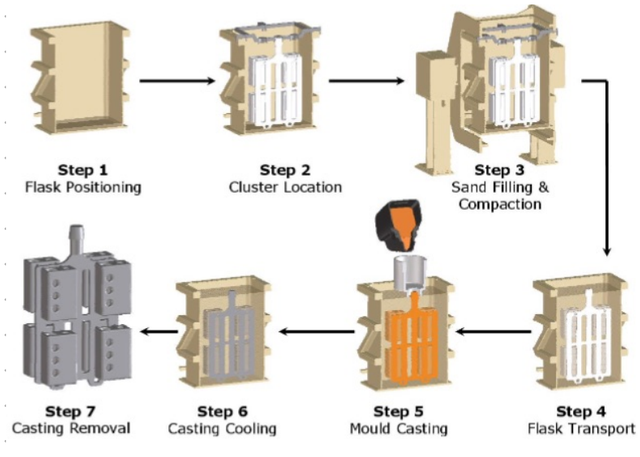


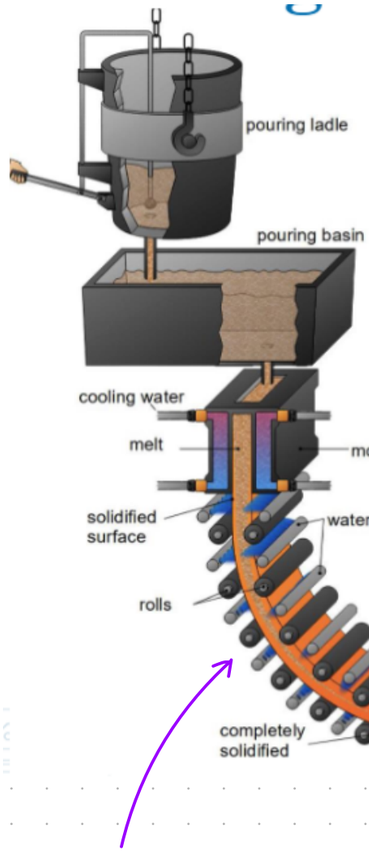
Lost-Foam Casting

expendable polystyrene patterns (vanishes) -> leave behind hollow cavities (filled by metal)

Pros:
- cost effective (mold-making / material removal),
- complex internal geometries / near-net shape,
- no draft angles required

Cons:
- limited surface finishes, material limit. (reactions w/ polystyrene foam), ↓ dimen. acc.



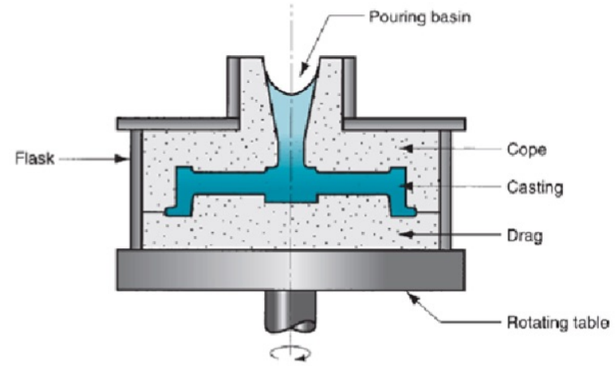


Semicentrifugal Casting

sand casting + centrifugal casting

Pros:
- centrifugal force -> density benefits,
- complex, non-cylindrical shapes w/ improved internal properties.

Cons:
- specialized equip. & mold design needed,
- limited achievable shapes vs. centrifugal casting.



Continuous Casting

molten metal river -> bars, rods, & beams

Pros:
- high production rates,
- minimal mat. waste,
- excellent dim. consistency & internal Q.C.,
- wide range of shapes / material categories

Cons:
- high initial cost: equip. & cont. production,
- limited to specific geometries: cont. withdrawal
- precise temp control & process monitoring.

Investment Casting

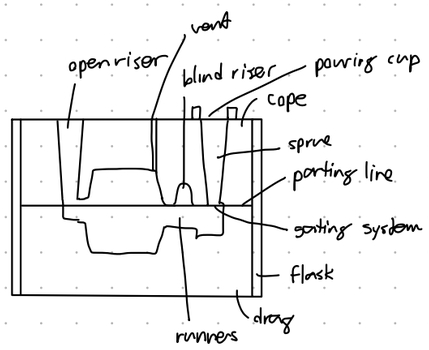
intricate wax patterns -> metal sculptures

Pros:
- exceptional dimen. accuracy & finish,
- wide range of material compatibility: high M.P. alloys, mold expansion during burnout: minimal draft angles.

Cons:
- ↑ costs & lead time vs other methods, delicate wax, smaller part sizes due to mold complexity.

Solidification Process

Gas Porosity:
tiny air bubbles trapped within solidifying metal.
Shrinkage:
molten metal fed into casting are inadequate.



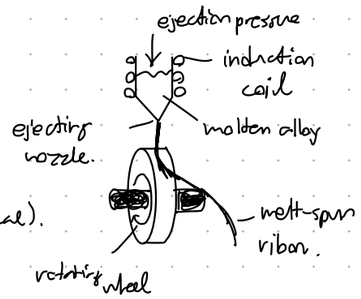
Open Mold
container in shape of desired part

Closed Mold
more complex mold geometry, needs gating-system

Expendable mold: mold destroyed after each cycle; low~med. prod. vol.
permanent mold: mold reused multiple times: high vol. prod. of identical pts.

Melt Spinning:

molten metal → hair-thin filaments via rapidly rotating wheels
→ exceptional strength & unique prop.
→ metallic threads (aerospace/medical).

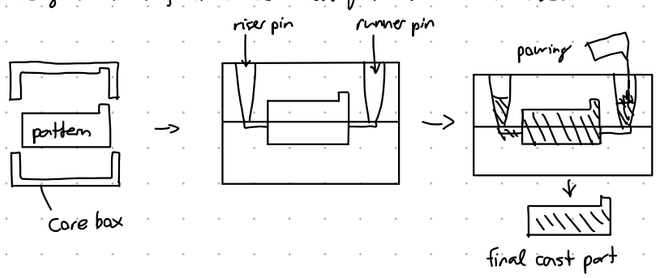


Sand Casting:

1. pattern creation (from metal or plastic) via core box
2. packed w/ binder-coated sand to form mold cavity
3. mold halves (cope & drag) are aligned
4. molten metal /alloy poured into cavity
5. cooling & solidification occurs
6. sand mold broken away to reveal casting
7. cleaned & machined

Characteristics: large-complex shapes, cost-effective for medium-low volume production, & excellent for creating internal cavities w/ cores.

Cons: lower dimensional accuracy vs permanent molds, rougher finish, & mold destroyed after each use.



Nucleation

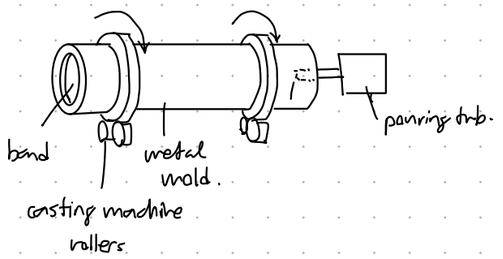
a tiny flicker that occurs when solidification begins
occurs when a net release of energy from liquid

Undercooling = MP - nucleation temp.
each nucleation creates a grain. (grain # ↑, prop. ↑)

Inoculation / Grain Refinement:

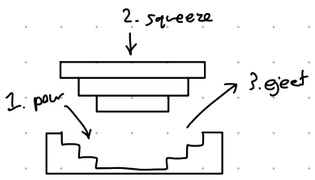
Centrifugal Casting:

spins molten metal into shape.
characteristics: creates strong, high density & uniformity cylindrical shapes, min. internal defects & gas porosity, & good for high vol. production of repetitive parts.
Cons: only cylindrical shapes & needs specialized equip. & mold design.

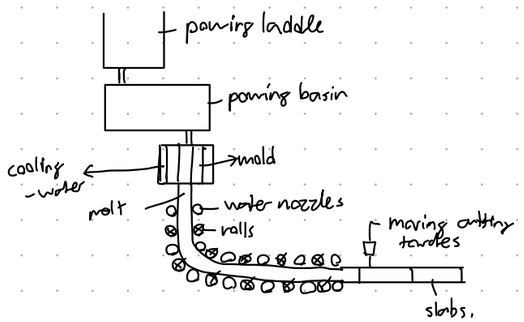


Die Casting (Squeeze Casting):

applies external forces to the mold
characteristics: superior dimensional accuracy vs. all other methods, enhanced mechanical properties via pressure-induced solidification, used for high-strength & wear resistant applications.
Cons: needs specialized high-pressure equip. & molds, limited to specific shapes compatible w/ its method.



Continuous Casting.

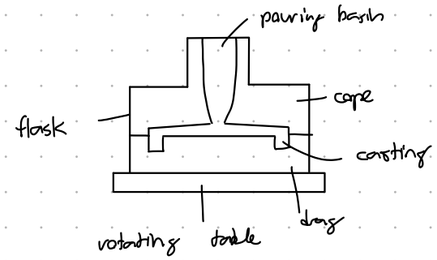


Lost Foam Casting:

uses expendable polystyrene patterns that vaporizes during pouring, leaving cavities for molten metal to fill
characteristic: cost effective by eliminating mold-making & pattern-removal steps, complex internal geometries (near-net shape casting), no draft angles needed.
cons: limited surface finish, mat. limits (reactions), & dimensional accuracy can be lower.

Semicentrifugal Casting:

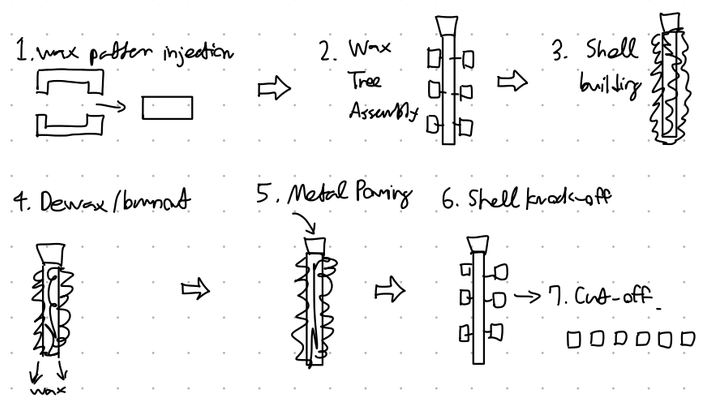
non-cylindrical shapes spun into shape too. Combination of sand casting & centrifugal casting.
characteristics: complex, non-cylindrical shapes, improved internal properties (higher density b/c of pressure).
Cons: specialized mold design & casting setup, limited shapes vs. centrifugal casting.



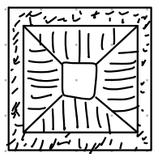
More/enhanced control over wall thickness & internal features vs. centrifugal casting

Investment Casting:

transforms intricate wax patterns into metal sculptures
characteristics: exceptional dimensional accuracy & finish, complex geometries ✓, wide range of mat. compatibility, min. draft angles needed.
Cons: high cost & longer lead times, delicate wax patterns need careful handling, & limited to smaller size due to mold complexity



Chill Zone: outside surface: fine-needle-like grains (fast cooling)
Columnar Zone: middle layer: elongated, columnar grains ⊥ to heat flow (slower cooling).
Equiaxed Zone: heart of casting, spherical grains w/ no orient.



Directional Solidification: manipulates heat flow to promote preferential grain growth.

Risers: reservoirs of liquid metal that feeds extra metal into the mold to compensate for shrinkage.
- blind riser: contained fully in mold cavity
- live riser: receives last hot metal that enters mold.

Riser Aids: exothermic sleeves that insulates material ↓ cooling rate,
Chills: improve efficiency to ↑ cooling rate (controll solidification rates)
- external chills: mass of high-heat capacity mat., ↑ cooling speed.
- internal chills: become a part of casting ↑ cooling/solidification.

Defect Elimination: uniform cross-sections, ribbons/fillets improve bosses, avoid sharp corners, ... etc