Introduction to Manufacturing, AGE-1320

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Manufacturing Engineering Technology in SI Units, 6^{th} Edition

Chapter 10: Fundamentals of Metal Casting

Chapter 11: Metal Casting Processes and Equipment

Chapter Outline

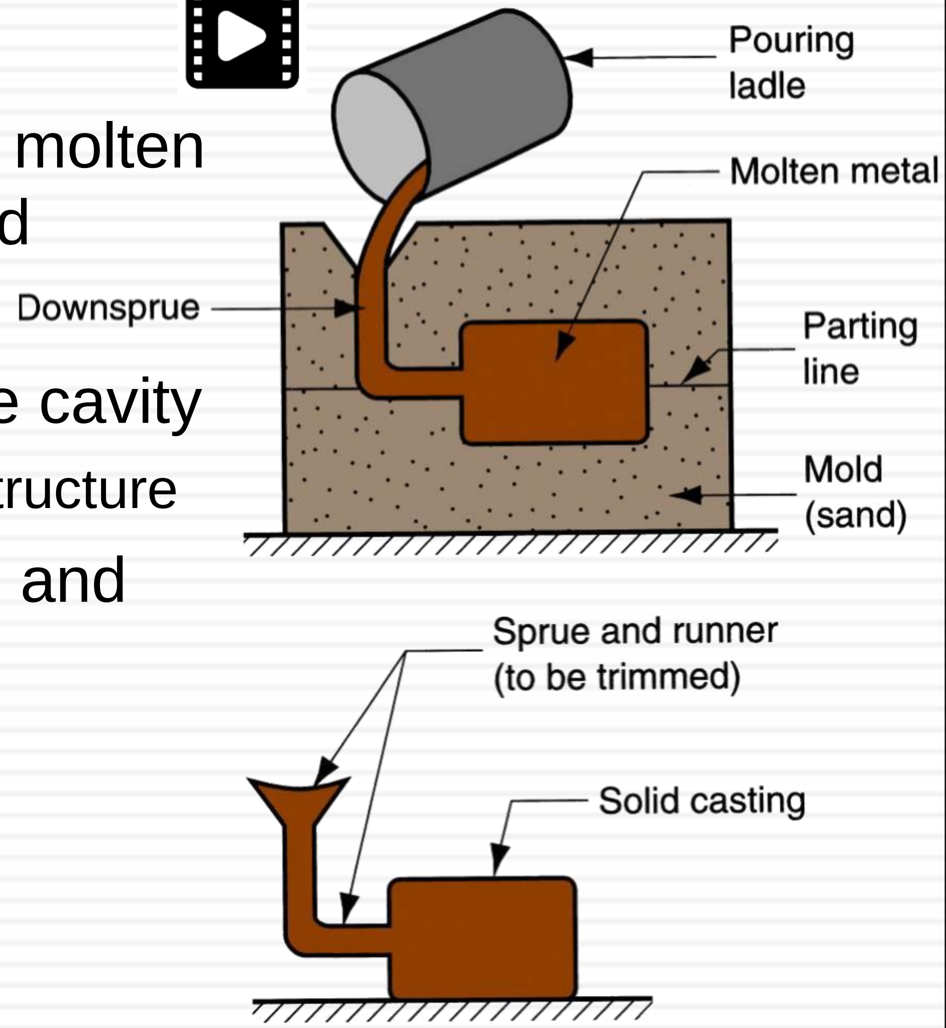
1. **Introduction to Casting**
2. **Casting Processes Overview**
3. **Casting Components & Materials**
4. **Gating & Specialized Processes**
5. **Precision & Permanent-Mold Processes**
6. **Defects & Safety**

1. Introduction to Casting

Introduction to Casting

What Is Casting?

- Shaping metal by pouring molten metal into a prepared mold
  - metal fills cavity shape
- Solidification occurs inside cavity
  - cooling rate affects grain structure
- Ideal for complex external and internal geometries
  - cores allow hollow shapes



Introduction to Casting

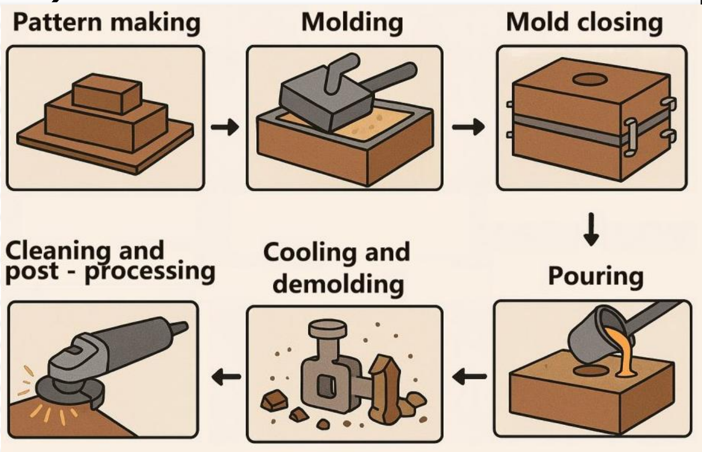
What Is Casting? (cont.)

- Suitable for small to extremely large parts
  - e.g. jewelry, engine blocks
- Works with almost all metals
  - especially those difficult to machine
- Used when machining would be too costly or impossible

Introduction to Casting

Core Operating Principles

1. Melting metal to required temperature (superheat ensures fluidity)
2. Pouring molten metal into mold through gating system (controls flow)
3. Metal fills cavity and displaces air (vents prevent gas entrapment)
4. Solidification begins at mold walls (directional cooling is desirable)
5. Shrinkage occurs during cooling (risers compensate for volume loss)
6. Final part removed after cooling, cleaned, inspected



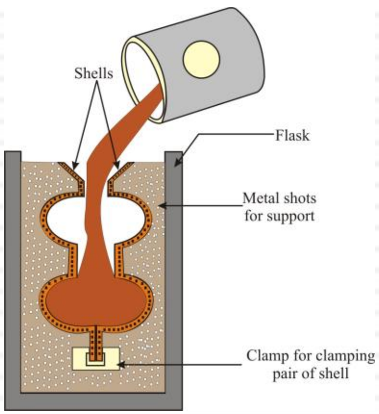
2. Casting Processes Overview

Casting Processes Overview

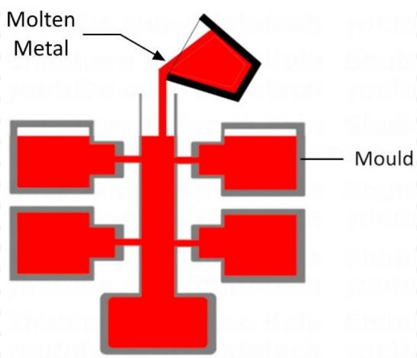
Classification of Casting Processes

- Expendable-mold:
  - permanent-pattern processes (sand casting, shell molding)
  - expendable-pattern processes (investment casting, lost-foam)
- Permanent-mold processes (permanent mold, die casting)

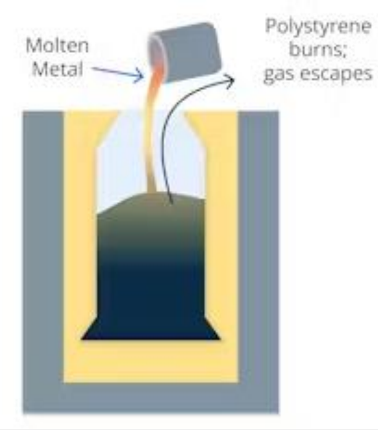
shell molding



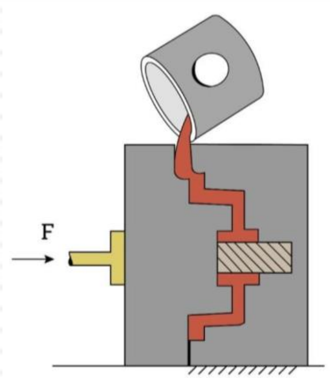
investment casting



lost foam



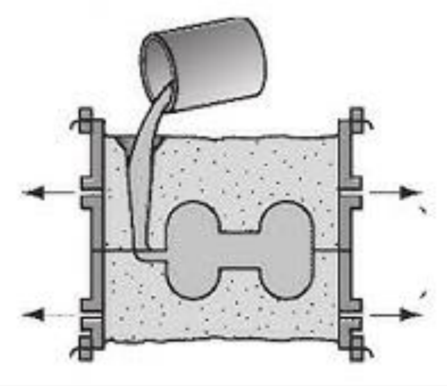
permanent-mold processes



Casting Processes Overview

Classification of Casting Processes (cont.)

- Vacuum and pressure-assisted processes (improve filling for thin walls)



vacuum molding

- Each process has distinct accuracy, cost, and production rate
- Selection depends on shape complexity, tolerance needs, and production volume

Casting Processes Overview

automotive casting

Applications of Casting

- Automotive housings, crankcases, pistons (aluminum & magnesium)
- Pumps, valves, pipe fittings (cast iron, bronze)
- Large components: engine blocks, turbine housings (sand casting)
- High-precision components: turbine blades, biomedical implants (investment casting)
- Complex thin-walled structures with minimal machining (die casting)
- Used across automotive, aerospace, biomedical, energy sectors

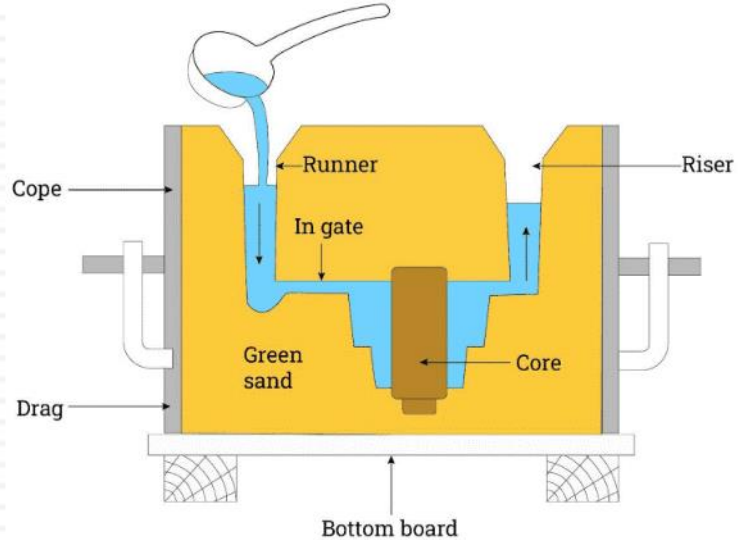
pump casting

implants: knee casting

electronics die casting

Casting Processes Overview

Sand Casting Overview



- Most widely used process (low cost, flexible, almost all metals)
- Uses expendable sand mold
  - shape formed by compacting sand around pattern
- Good for large and heavy parts (hundreds of kilograms to several tons)

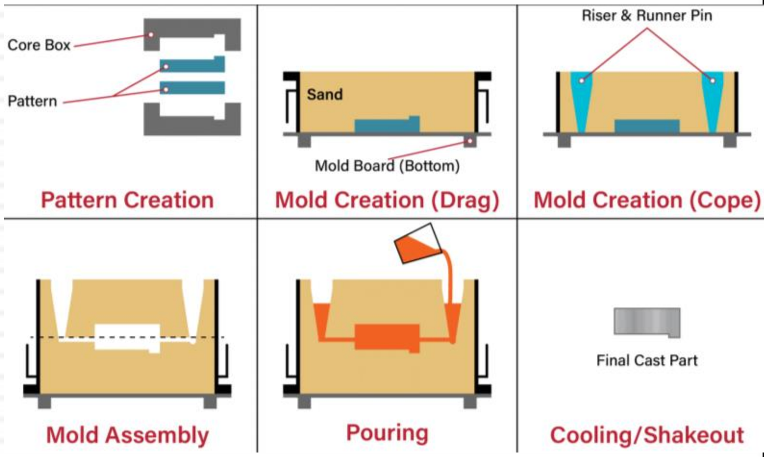
- Tolerances moderate, surface finish depends on sand grain size
- Leads production volume for ferrous castings
- Supports simple to moderately complex shapes

3. Casting Components & Materials

Casting Components & Materials

Sand Casting Workflow

1. Pattern making
2. Preparing mold halves
   - cope and drag (packed with sand around pattern)
3. Inserting cores if internal cavities required
   - core prints support cores
4. Melting and pouring metal
   - ladles, controlled temperature
5. Solidification inside mold
   - cooling rate affects microstructure
6. Shakeout and removal of sand
7. Cleaning, trimming, inspection of final casting



Casting Components & Materials

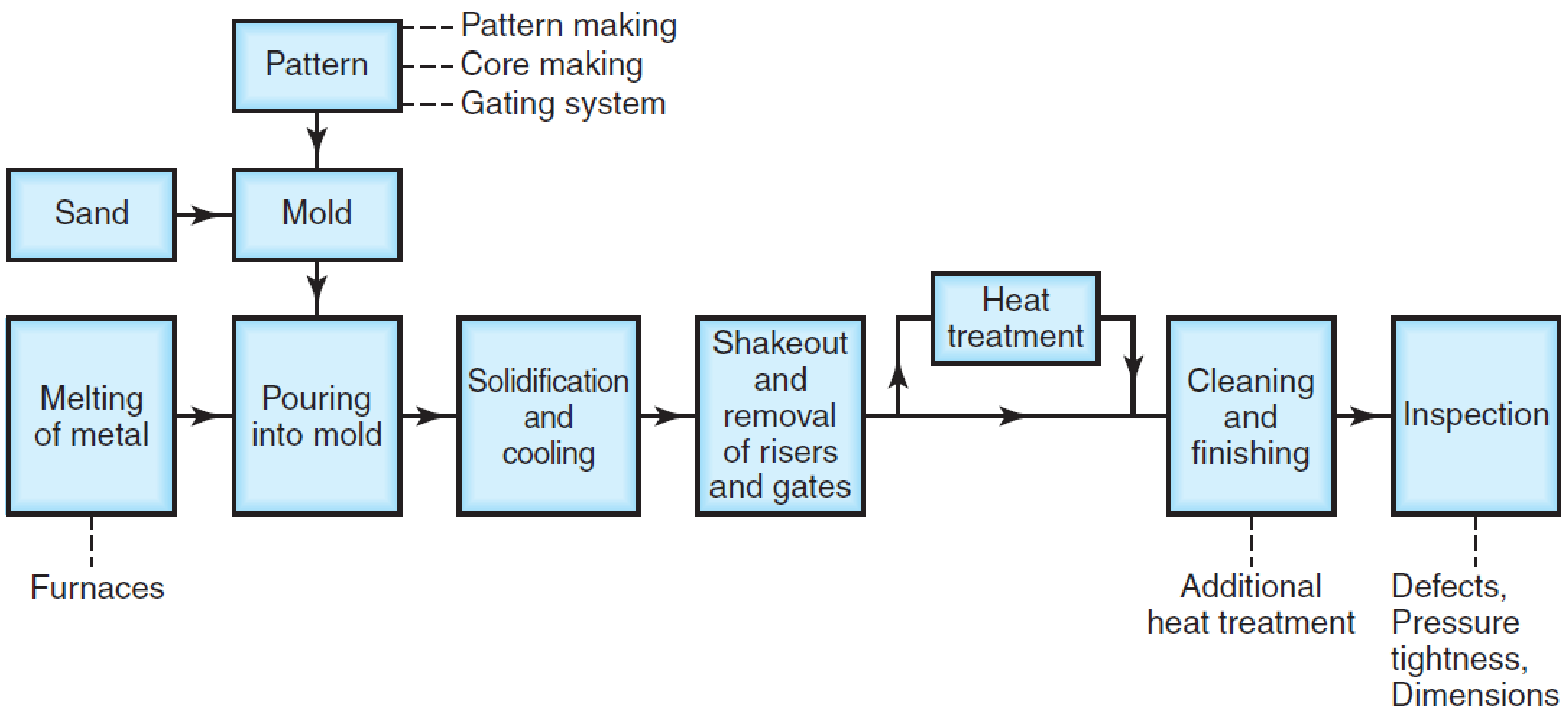


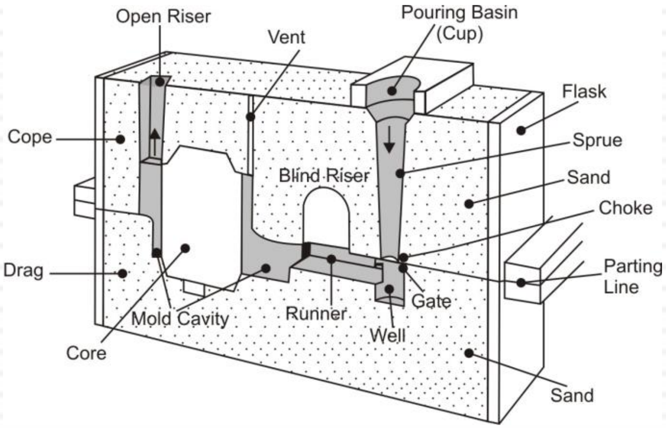
Fig. 11.2 outline of production steps in a typical sand-casting operation

Casting Components & Materials

cold-box mold

Sand Molds

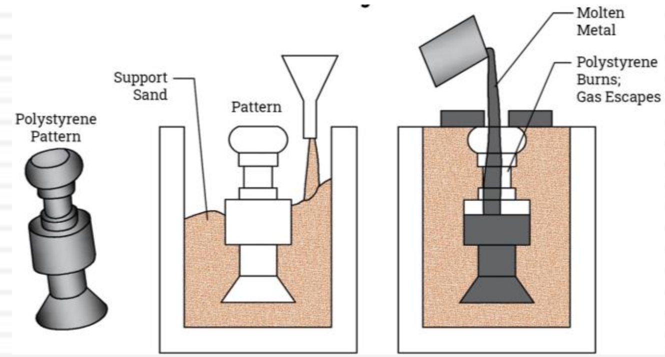
- Green-sand molds (moist clay-bonded sand; inexpensive and reusable)
- Cold-box and no-bake molds (chemically bonded for higher strength)
- Mold components: cope, drag, flask (maintain mold geometry)
- Vents allow air and gases to escape (reduces porosity)
- Chills inserted to accelerate local cooling (improves grain structure)
- Mold strength, permeability, collapsibility must balance

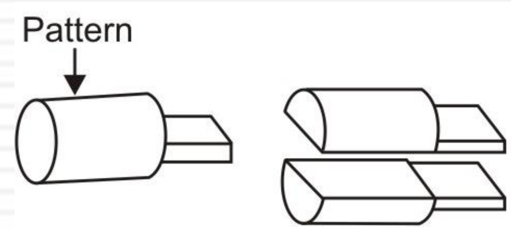


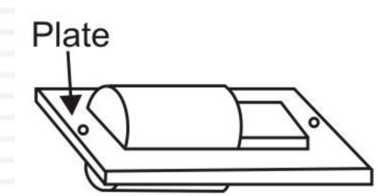
Casting Components & Materials

Patterns

- Create the cavity shape inside the mold (primary shape-making tool)
- Materials: wood (easy to shape), plastic (durable), metal (high precision)
- Types: single-piece, split patterns, match-plate patterns
- Pattern allowances: shrinkage, machining, draft (facilitates removal)
- Proper surface finish improves mold quality
- Pattern wear affects accuracy over long production runs



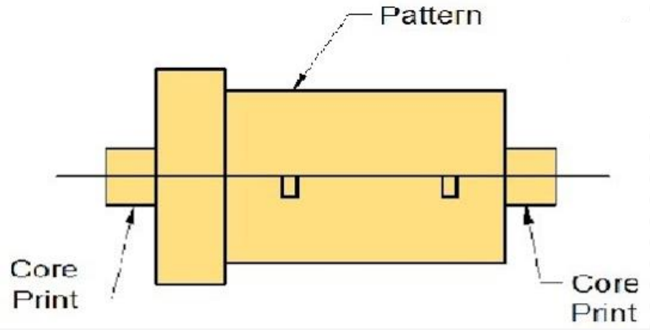




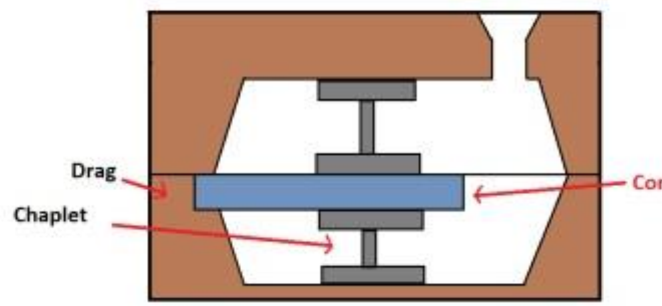
Casting Components & Materials

Cores

- Form internal cavities within castings (hollow spaces, passages)
- Made of special sand mixtures (stronger than mold sand)



- Core prints support core placement inside mold
- Chaplets help support heavy or fragile cores during pouring



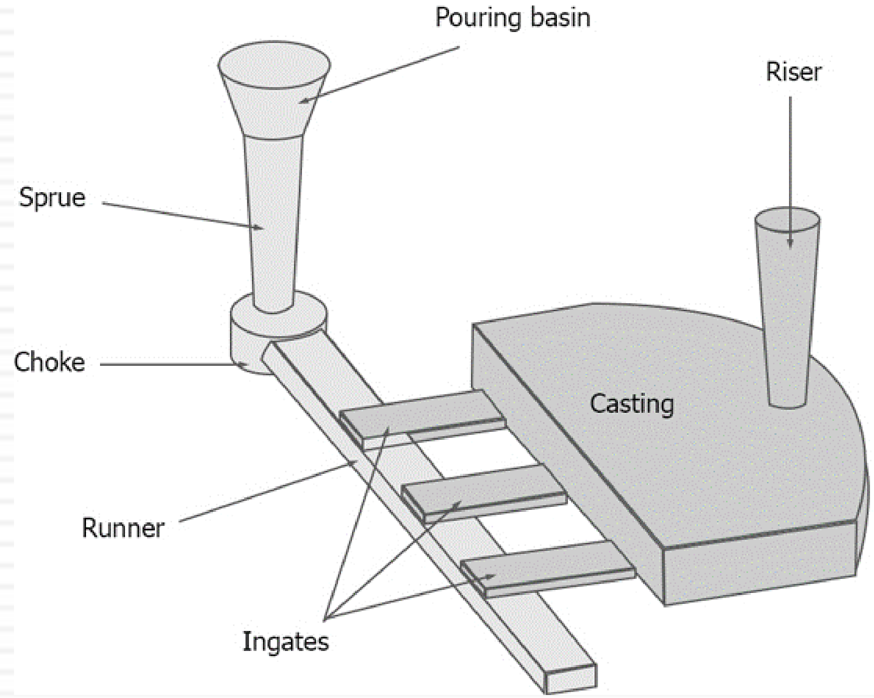
- Core collapse necessary after solidification (helps removal)
- Must withstand high temperature without distortion

4. Gating & Specialized Processes

Gating & Specialized Processes

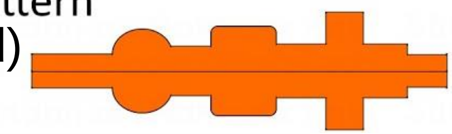
Gating System

- Pouring basin directs metal to sprue (controls entry)
- Sprue leads to runner system (distributes flow)
- Gates deliver molten metal into cavity (low turbulence)
- Choke regulates flow rate (prevents erosion and turbulence)
- Risers feed shrinking regions during solidification (avoid cavities)
- Proper gating reduces porosity, inclusions, misruns

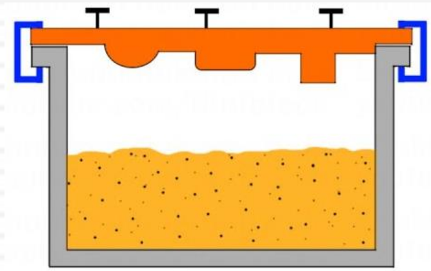


Gating & Specialized Processes

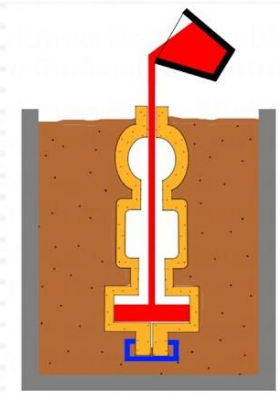
Shell Molding



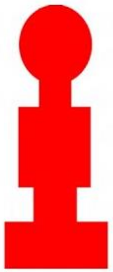
- Thin hardened resin-coated sand shell forms the mold



- Produces smooth surfaces & high accuracy
- Good for medium to large production volumes



- Suitable for small-to-medium sized components



- Lower permeability → slower cooling → finer surface finish
- Higher mold cost but reduced cleaning and finishing time

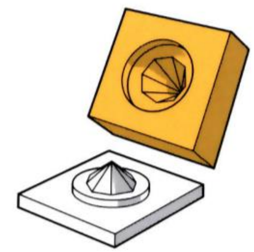
Gating & Specialized Processes

Plaster & Ceramic Mold Casting

- Plaster or ceramic slurry poured over patterns (forms precise cavity)
- Suitable for Al, Mg, nonferrous alloys (no steel/cast iron)
- Low permeability molds → slower cooling → improved surface finish
- Good for complex geometries, thin sections
- Longer mold preparation time compared to sand
- Limited to lower-temperature metals (mold material constraints)

Pattern

4 The slurry is poured over a pattern made of wood, metal, plaster, plastic, etc. It is then allowed to gel in about 2–3 min.



Stripping

5 The gelled refractory mass is stripped from the pattern by hand or by a mechanical stripping mechanism.

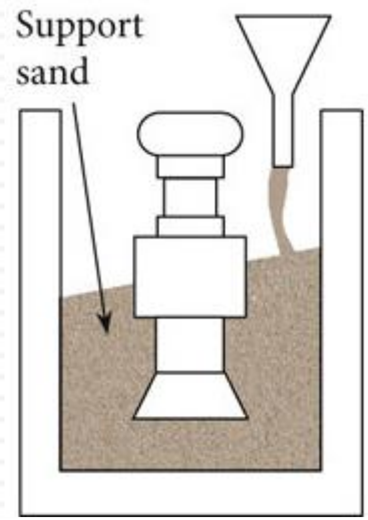
Burnoff

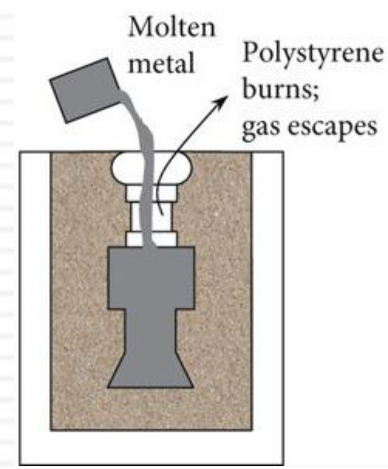
6 The mould is ignited. It burns until all volatiles are consumed. It sets up the "microcrazed" structure.

Gating & Specialized Processes

Evaporative-Pattern (Lost-Foam) Casting

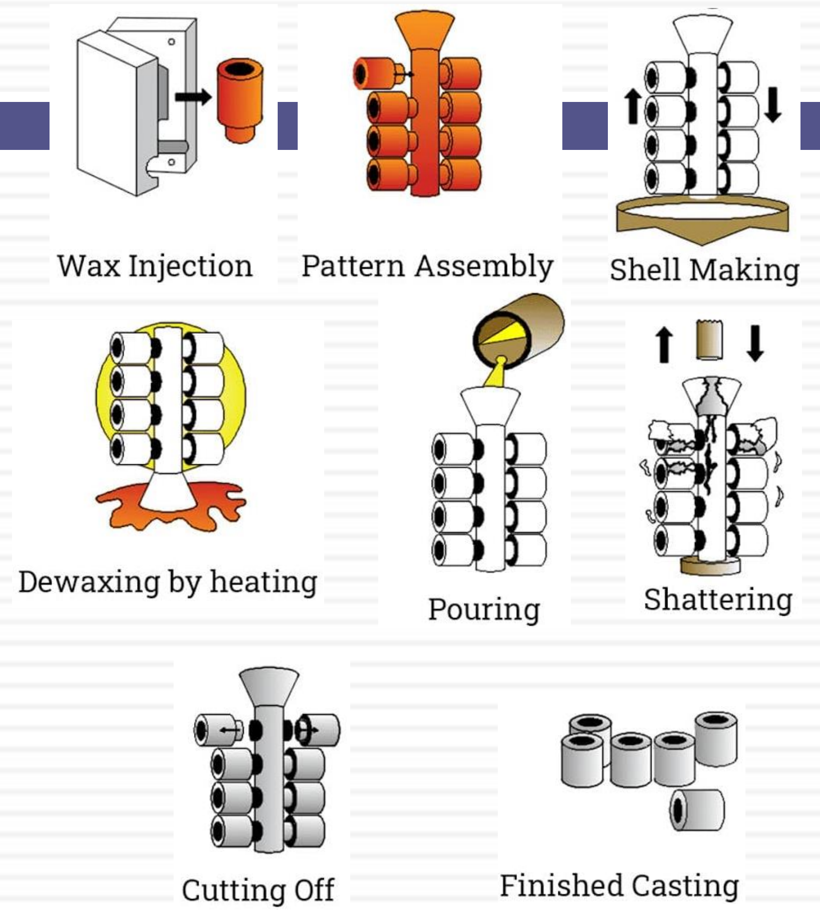
- Uses expendable foam pattern (vaporizes during pouring)
- No parting lines → excellent dimensional accuracy
- Simplifies mold preparation (no need to remove pattern)
- Reduces cleaning operations after casting
- Good for complex shapes and prototypes
- Requires careful foam pattern coating for surface finish





5. Precision & Permanent-Mold Processes

Precision & Permanent-Mold Processes



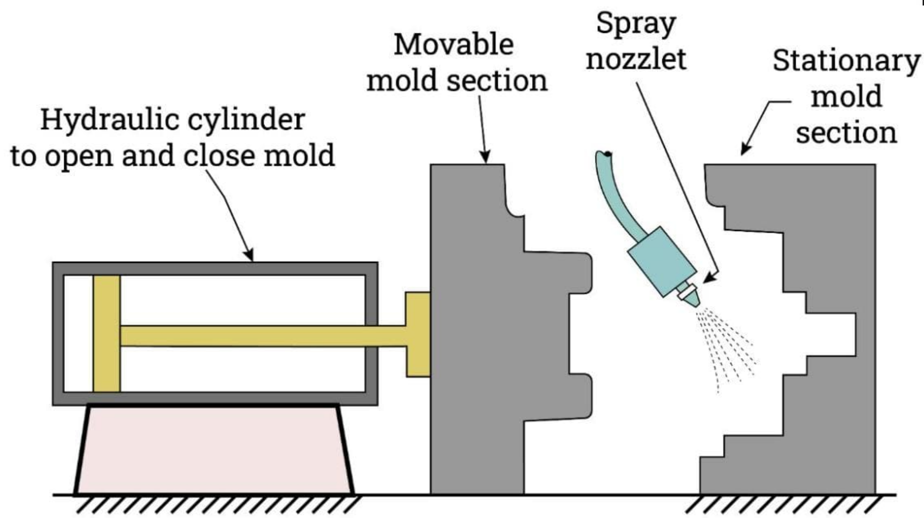
Investment Casting (Lost-Wax)

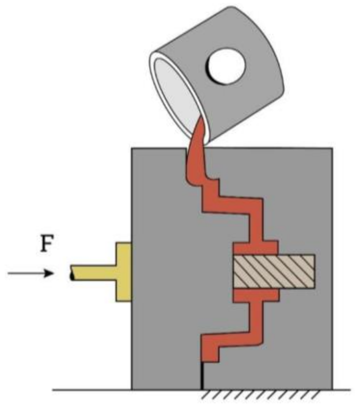
- Wax patterns assembled into "tree" (gated system)
- Dipped in ceramic slurry to form shell mold
- Shell dried, wax melted out in autoclave (investment stage)
- Molten metal poured into preheated ceramic mold
- Excellent accuracy and surface finish (±0.05 mm typical)
- Ideal for turbine blades, medical implants, precision components

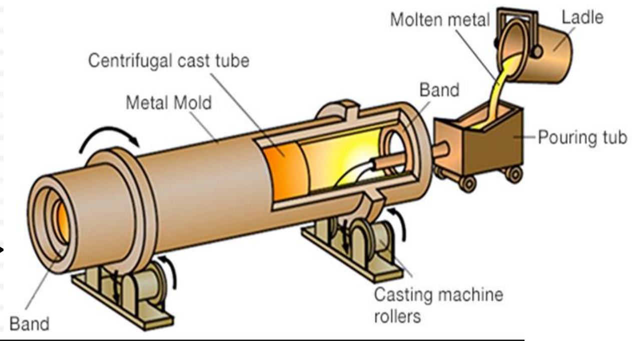
Precision & Permanent-Mold Processes

Permanent-Mold Casting

- Reusable metal molds (steel, cast iron, graphite)
- Rapid cooling → fine grain structure and strong components
- Good surface finish
- Limited to lower melting point metals (Al, Mg, Zn)
- Moderate tooling cost, high production rate
- Variants such as [vacuum casting]() and centrifugal casting →



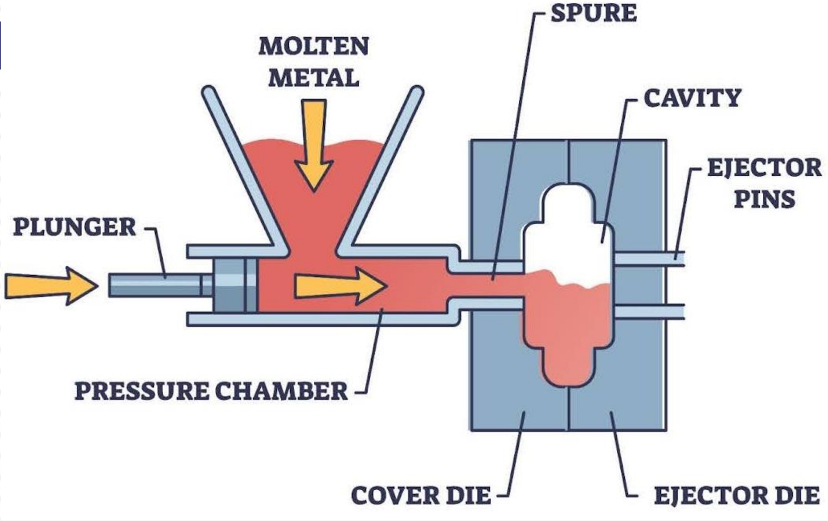




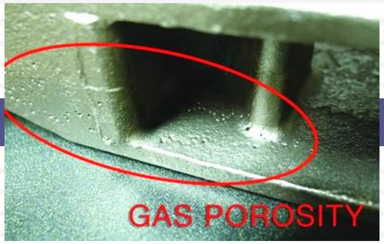
Precision & Permanent-Mold Processes

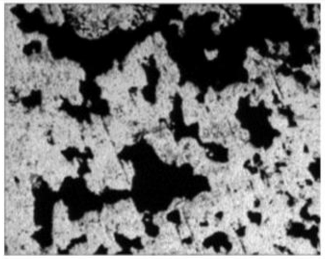
Die Casting

- Molten metal injected under high pressure into steel mold
- Extremely high production rate (automated)
- Excellent surface finish, thin walls possible
- Ideal for Zn, Al, Mg alloys
- Good dimensional accuracy (close tolerances)
- Not suitable for high-melting-point ferrous metals



Precision & Permanent-Mold Processes



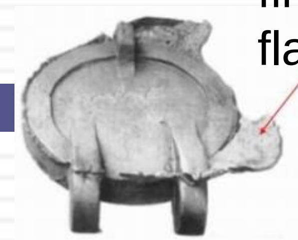

Shrinkage porosity 50X

Capabilities & Limitations

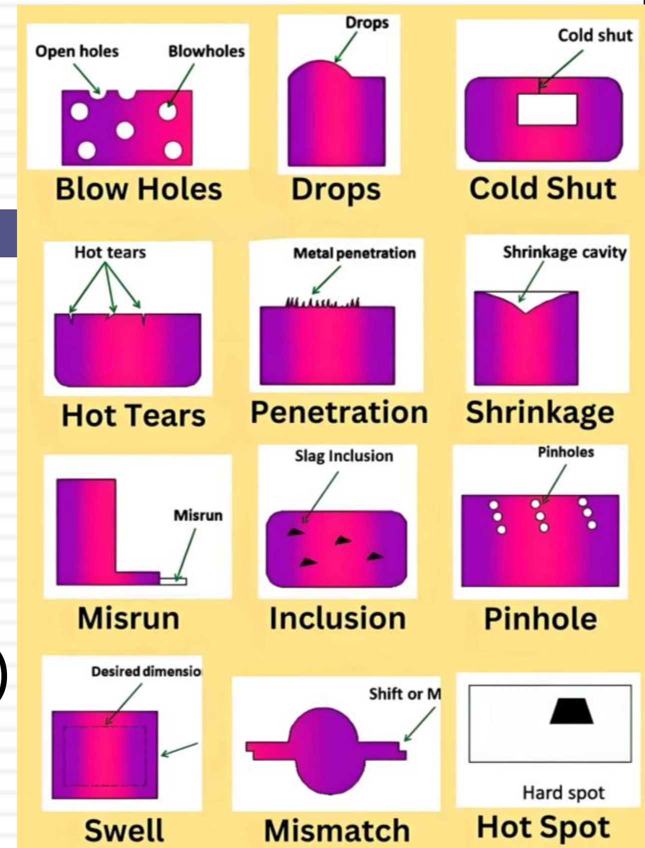
- Capabilities:
  - Complex shapes with internal cavities (cores)
  - Large and small components possible
  - Works with most metals
  - Near-net-shape reduces machining time
  - High production rates in automated processes
  - Good repeatability with permanent molds
- Limitations:
  - Porosity (gas and shrinkage)
  - Surface roughness varies by process
  - Dimensional accuracy depends on mold material
  - Mold wear in high-temperature alloys
  - Long cooling times for thick sections

6. Defects & Safety

Defects & Safety



fins/
flash



Casting Defects

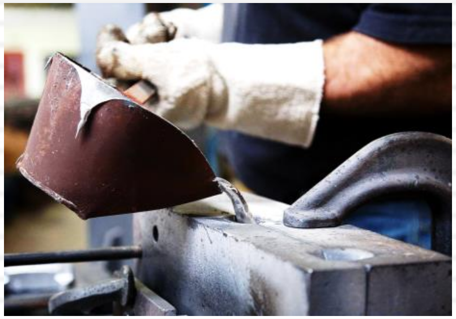
- Metal projections: fins, flash, run-out (poor mold assembly)
- Cavities: gas porosity, shrinkage cavities (inadequate venting/feeding)
- Discontinuities: cracks, hot tears
- Defective surfaces: roughness, fusion, penetration (poor sand quality)
- Incomplete casting: misruns, cold shuts (low fluidity or incorrect gating)
- Incorrect dimensions/shape: mold shift, warping
- Inclusions: slag, oxides (poor melting or turbulence)

slag defects

Defects & Safety

Casting Safety

- Molten metal splash hazards (use proper PPE, face shields)
- High temperatures during pouring (heat-resistant gloves, aprons)



- Fume and gas release from molds (good ventilation required)
- Moisture in molds can cause explosions (ensure molds are fully dried)
- Proper ladle handling and pouring posture (training essential)

- Maintain safe distance during pouring and shakeout