Material Engineering Department
General Materials Branch

Fourth Class

Casting Technology

Lecture Seven : Die Casting

Class Code :ofp4npn

Die Casting

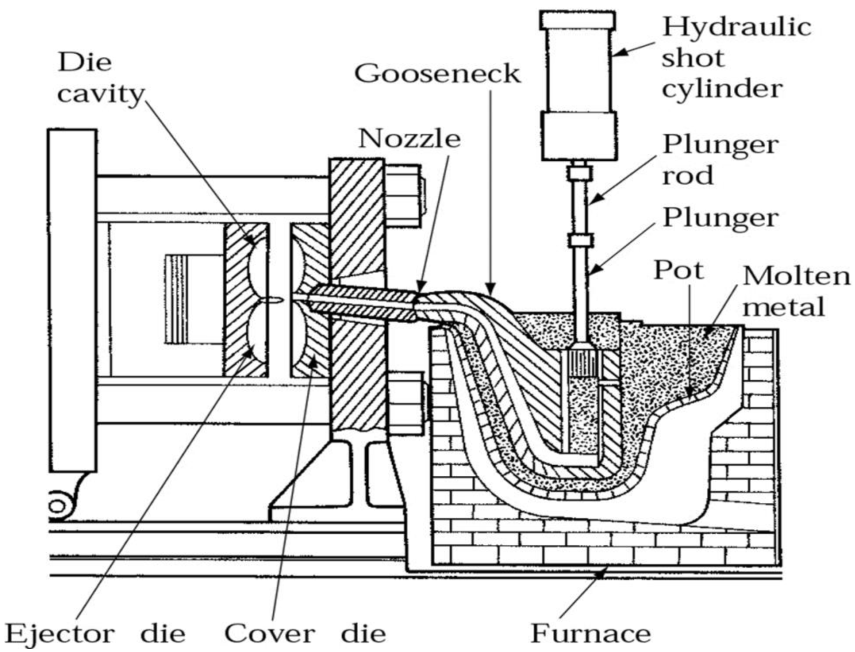
- Die casting is a Permanent-Mold Casting process in which the molten metal is injected into the mold cavity under high pressure. Typical pressures are 7 to 350 MPa .
- There are two main types of die casting machines:

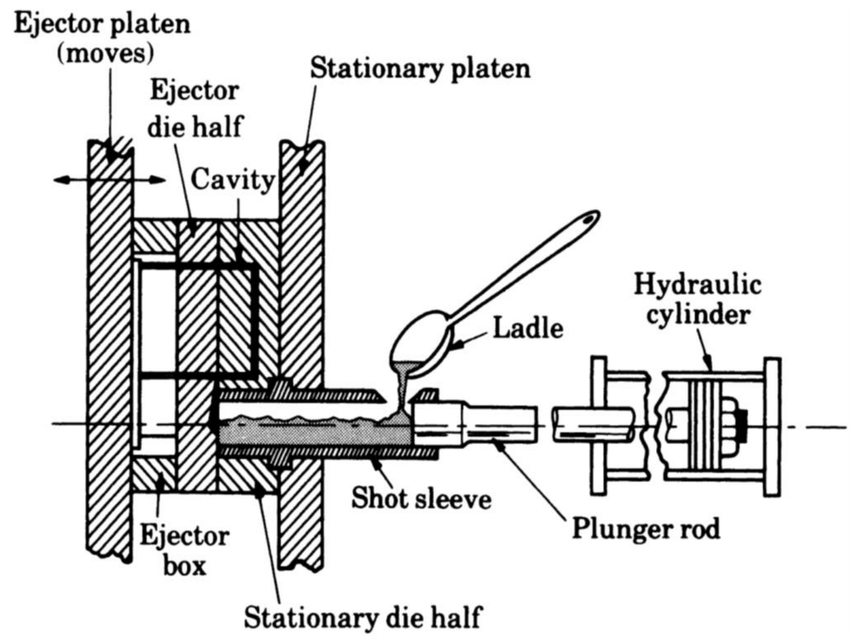
1. Hot- Chamber die casting Machine
2. cold-chamber die casting Machine .

Hot- and Cold-Chamber Die-Casting

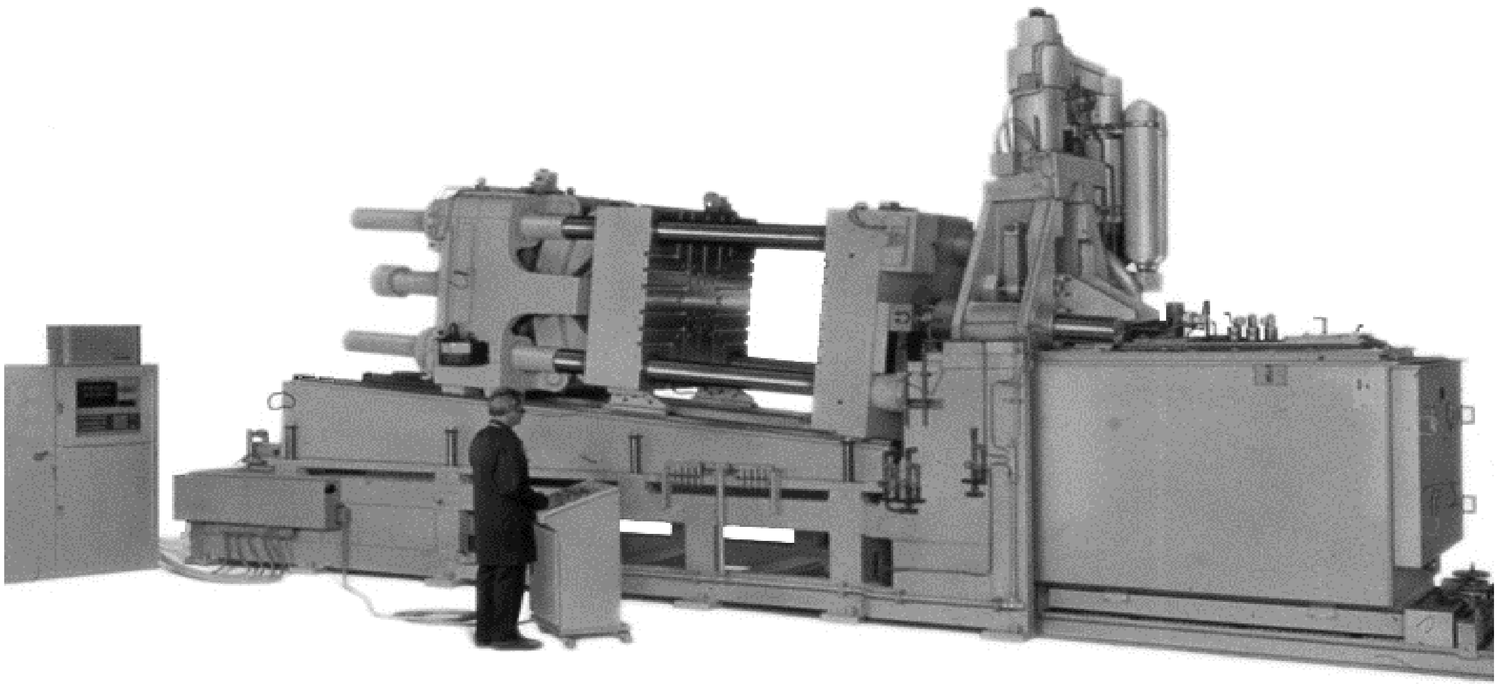
Schematic illustration of the hot-chamber die-casting process

Schematic illustration of the cold-chamber die-casting process.



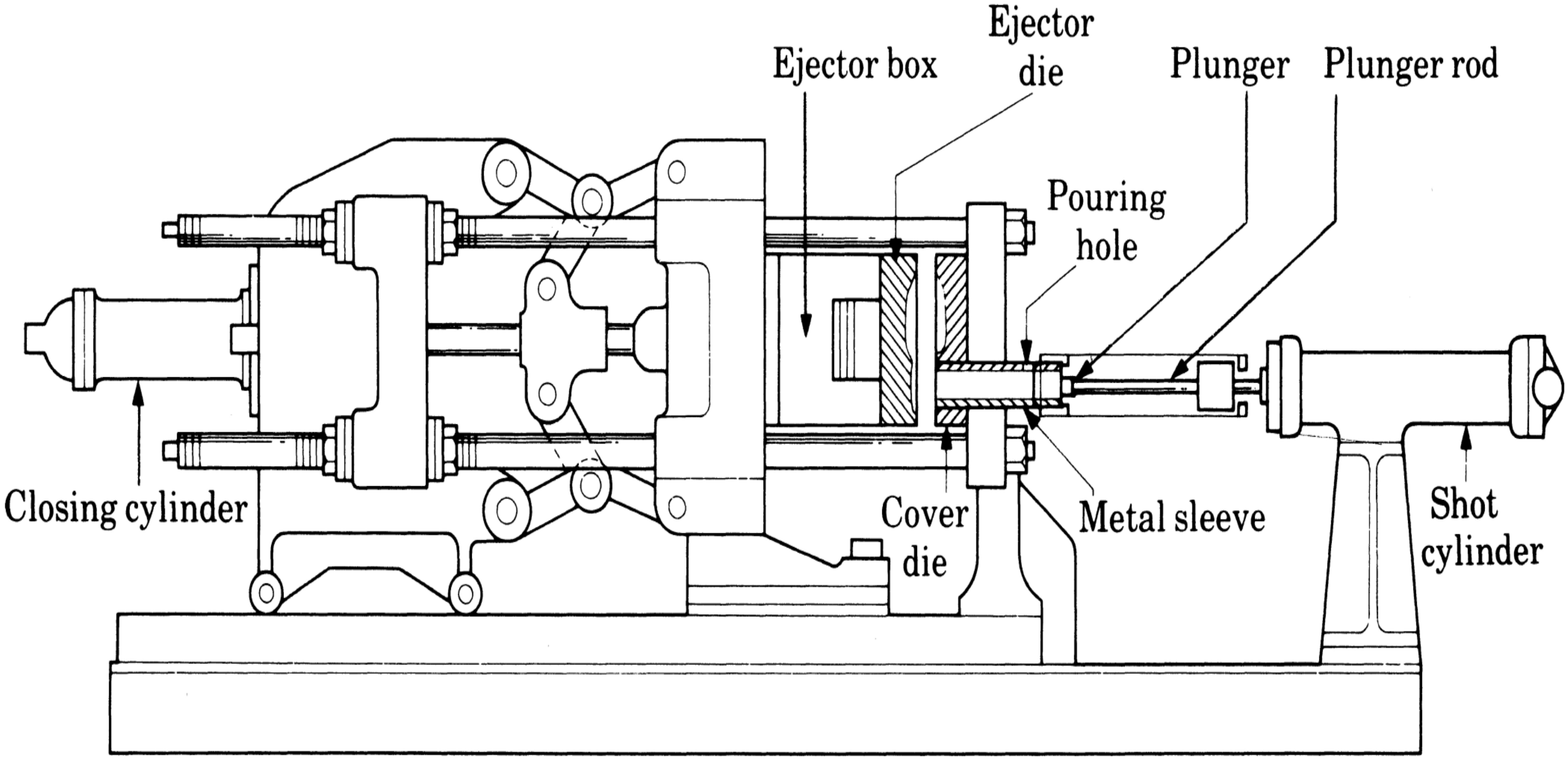


Hot-Chamber Die-Casting Machine

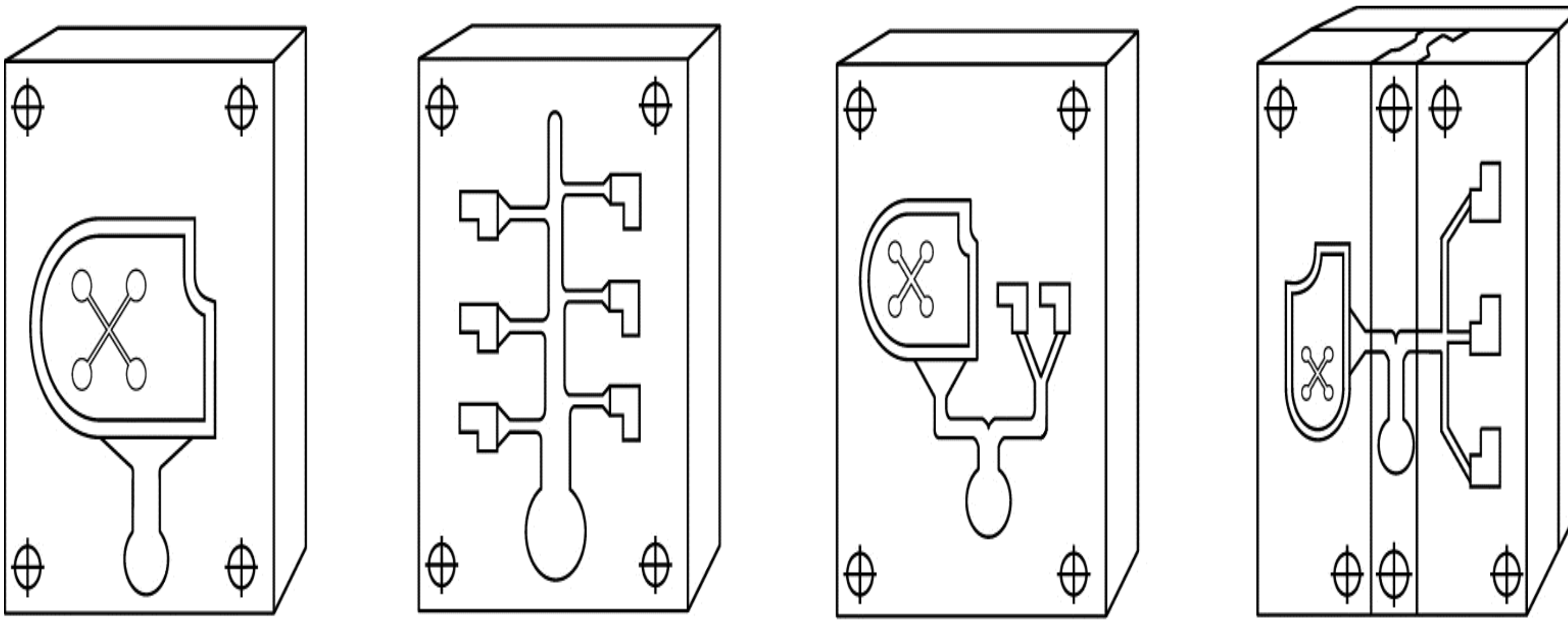


800-ton hot-chamber die-casting machine, DAM 8005 (made in Germany in 1998). This is the largest hot-chamber machine in the world and costs about $1.25 million

Cold-Chamber Die-Casting Machine



Process Capabilities and Machine Selection

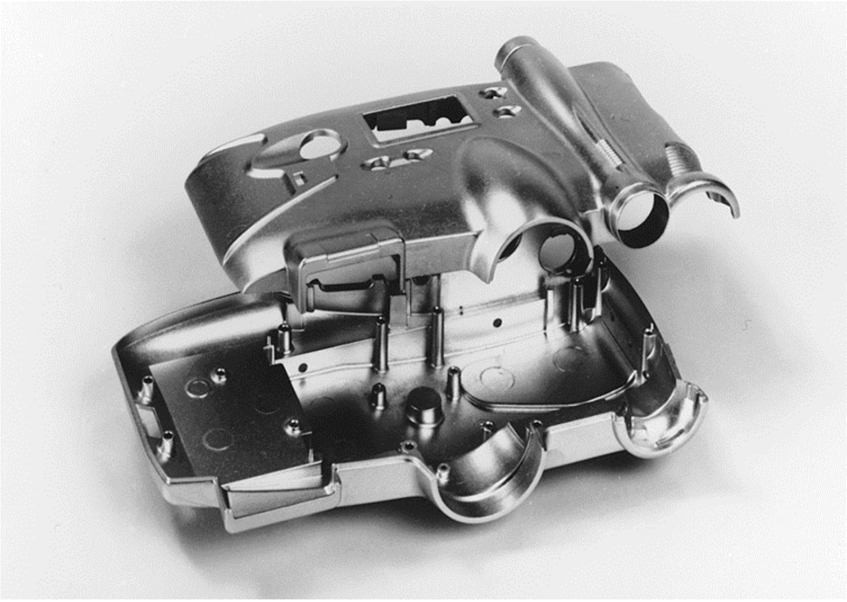


(a) Single-cavity die (b) Multiple-cavity die (c) Combination die (d) Unit die

Die-Casting Examples

The Polaroid PDC-2000 digital camera with a AZ91D die-cast, high purity magnesium case.

Two-piece Polaroid camera case made by the hot-chamber die Casting process.



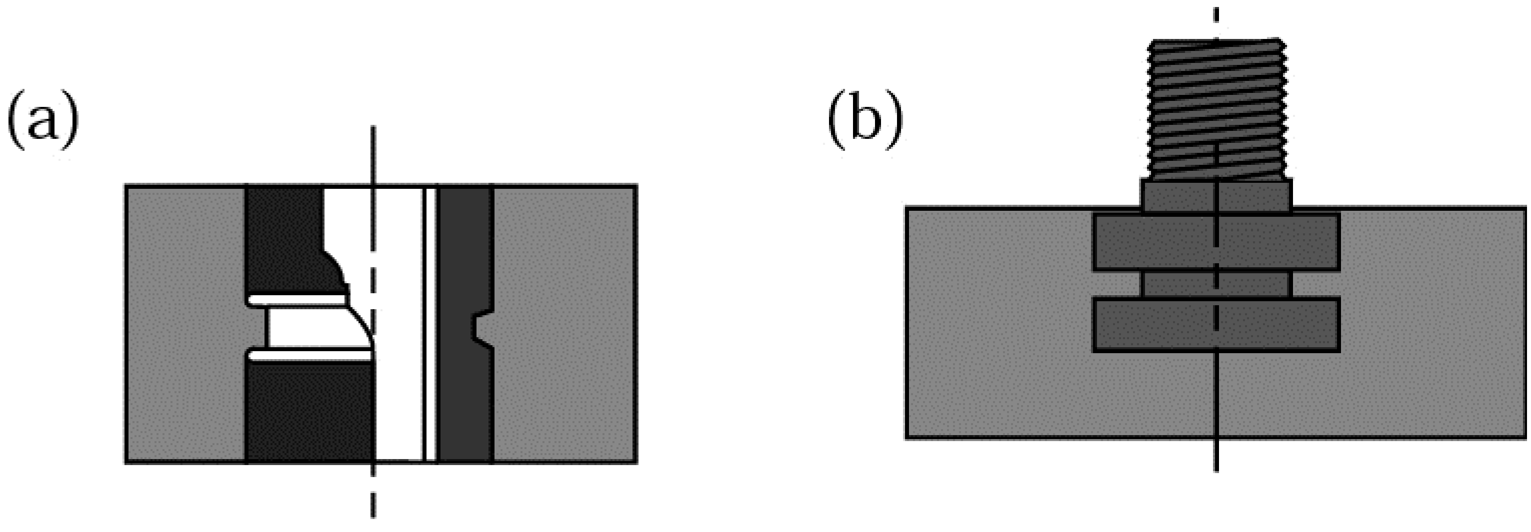
Process Capabilities and Machine Selection

Properties and Typical Applications of Some Common Die-casting Alloys

Alloy	Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation in 50 mm (%)	Applications
Aluminum 380 (3.5 Cu–8.5 Si)	320	160	2.5	Appliances, automotive components, electrical motor frames and housings
13 (12 Si)	300	150	2.5	Complex shapes with thin walls, parts requiring strength at elevated temperatures
Brass 858 (60 Cu)	380	200	15	Plumbing fixtures, lock hardware, bushings, ornamental castings
Magnesium AZ91 B (9 Al-0.7 Zn)	230	160	3	Power tools, automotive parts, sporting goods
Zinc No. 3 (4 Al)	280	—	10	Automotive parts, office equipment, household utensils, building hardware, toys
No. 5 (4 Al-1 Cu)	320	—	7	Appliances, automotive parts, building hardware, business equipment

Source: American Die Casting Institute.

Process Capabilities and Machine Selection



Examples of cast-in- place inserts in die casting.

(a) Knurled bushings.

(b) Grooved threaded rod.

Important Terms in Die Casting

1. Biscuit: Excess of ladled metal remaining in the shot sleeve of the cold chamber process. It is a part of the cast shot and is ejected from the die with the runner and casting
2. Blister A surface bubble caused by the expansion of entrapped gas as a result of excess heat.
3. Casting rate The average quantity of shots that can be produced from a particular die in one hour of constant running.
4. Casting/shot ratio Volume or weight of usable casting product divided by the total volume or weight of metal injected into the die that is expressed as a percentage.

Important Terms in Die Casting

5. Casting yield The net number of acceptable castings that are produced from a production run compared to the gross number of shots. It is usually expressed as a percentage
6. Casting cycle The total number of events required to produce a high pressure die casting that usually consists of metal injection (including cavity fill) solidification, ejection, and die spray
7. Flash formation of flash is common in die casting, in which the liquid metal under high pressure squeezes into the small space between the die halves at the parting line or into the clearances around the cores and ejector pins. This flash must be trimmed from the casting, along with the sprue and gating system.

Die Casting

- The Advantages of die casting include

1. High production rates possible
2. Economical for large production quantities
3. Close tolerances possible, on the order of .076 mm(0.003inch)

Design Considerations

1. Maintaining a consistent wall thickness
2. Using gradual transitions from surface to surface
3. Eliminating large metal masses
4. Using comers, fillets, and radii to assist with metal flow
5. Using ribs to facilitate metal flow
6. Maintaining a sufficient draft angle

Gating System Design

All of these methods attempt to take into account the influence of the following key variables:

1. Part shape
2. Internal quality
3. Surface quality
4. Mechanical properties
5. Die temperature
6. Die erosion

Gating System Design

7.Die material

8. Die venting

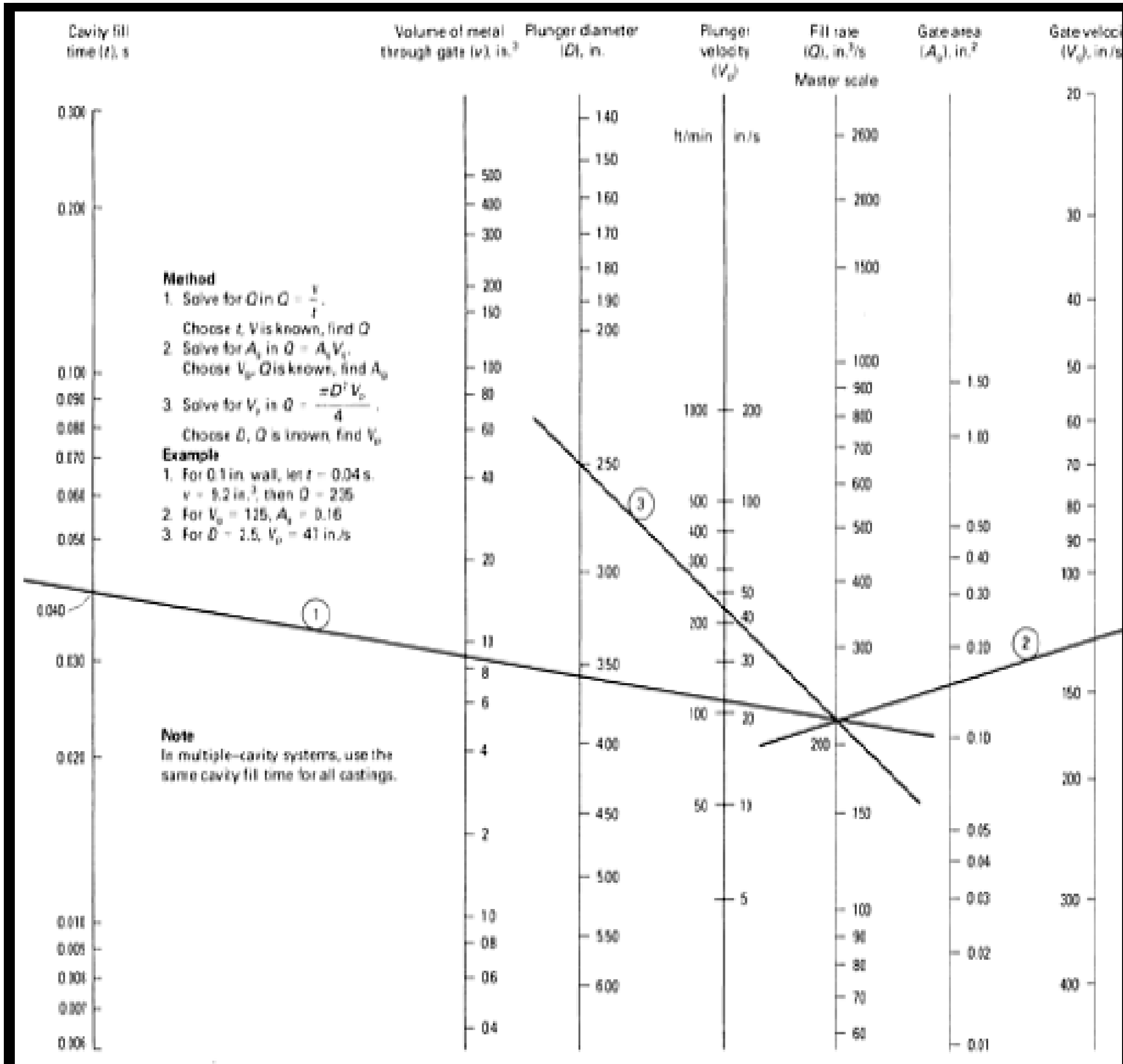
9. Metal temperature

10. Metal fluidity

11. Metal heat content

12. Metal microstructure

Gating System Design



Die Casting Design

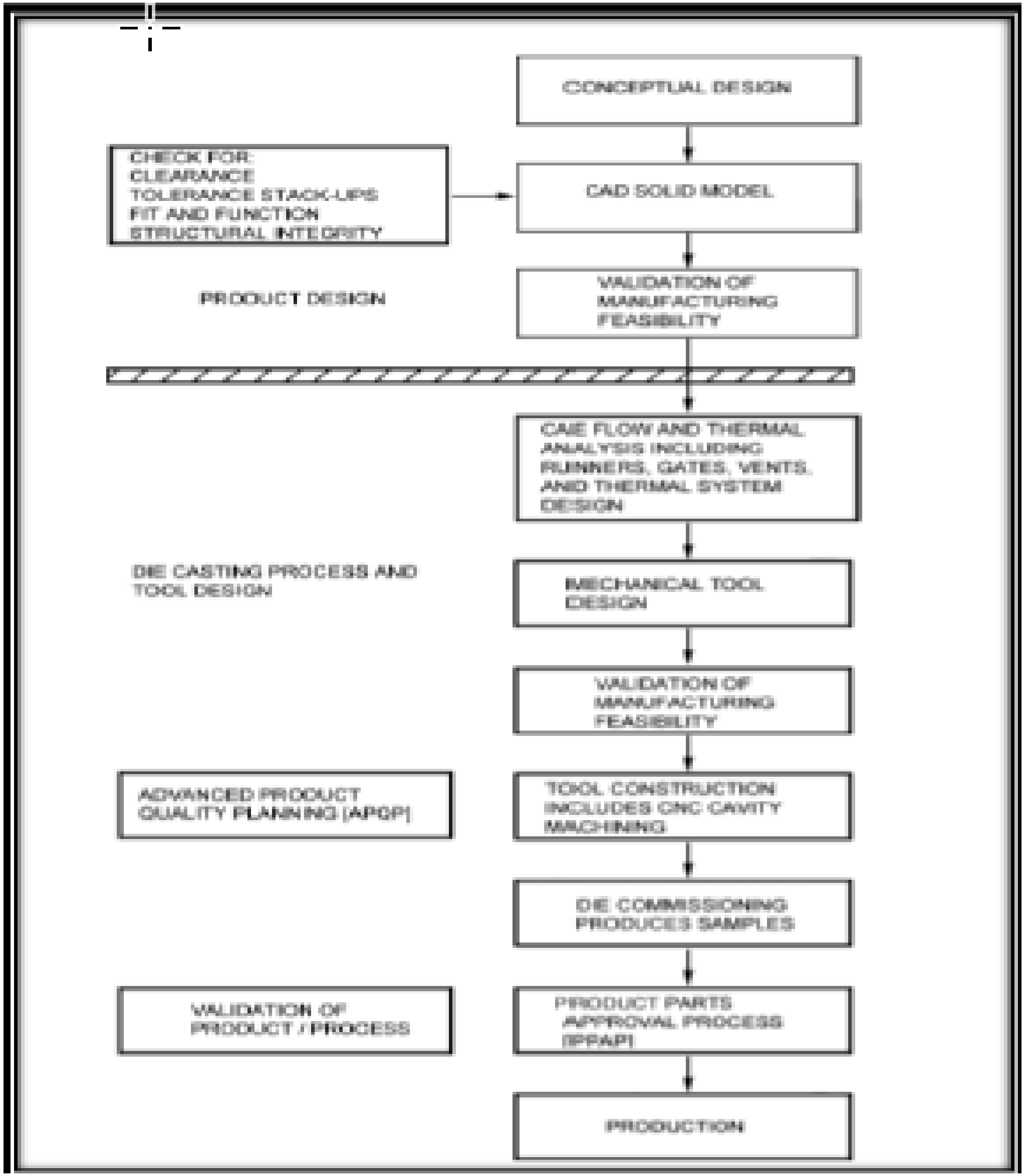
- **1.Gating**
- ***2.Metal Injection***
- **3.Die Casting Defects**
    a) Mechanical problems in the die
    b) Metallurgical problems in the molten alloy
    c) The interaction of heat flow and fluid flow
- **4.Mechanically induced defects**
- **5.Metallurgical Defects**

Die Casting Design

6. **Interaction of Heat Flow and Fluid Flow.**
7. ***Cold shuts***
8. ***Gas porosity***
    a) Too empty a shot sleeve (excessive diameter or length)
    b) Inadequate venting
    c) Excessive use of lubricant
    d) Residual moisture from sprays
    e) Poor metal flow patterns that prevent venting

Die Casting Design

9. ***Shrinkage***
10. ***Soldering***
11. ***Heat check fins***


CONCEPTUAL DESIGN
CHECK FOR:
CLEARANCE
TOLERANCE STACK-UPS
FIT AND FUNCTION
STRUCTURAL INTEGRITY
CAD SOLID MODEL
PRODUCT DESIGN
VALIDATION OF MANUFACTURING FEASIBILITY
CAE FLOW AND THERMAL ANALYSIS INCLUDING RUNNERS, GATES, VENTS, AND THERMAL SYSTEM DESIGN
DIE CASTING PROCESS AND TOOL DESIGN
MECHANICAL TOOL DESIGN
VALIDATION OF MANUFACTURING FEASIBILITY
ADVANCED PRODUCT QUALITY PLANNING [APQP]
TOOL CONSTRUCTION INCLUDES CNC CAVITY MACHINING
DIE COMMISSIONING PRODUCES SAMPLES
VALIDATION OF PRODUCT / PROCESS
PRODUCT PARTS APPROVAL PROCESS [PPAP]
PRODUCTION

Shrinkage Calculation

$$\%P = \frac{\beta V^*}{V_c} + \left(\phi \frac{T \rho L}{(237\ K) P} \right) (\nu - \nu^*) \qquad (1.2)$$

where

$\%P$ = percent porosity,
β = solidification shrinkage factor in percent,
V^* = volume of liquid in casting cavity that is not supplied liquid during solidification in cubic centimeters,
V_c = volume of the casting cavity in cubic centimeters,
T = temperature of the gas in the casting cavity in degrees Kelvin,
P = pressure applied to the gas during solidification in atmospheres,
ϕ = fraction of the gas that does not report to the solidification shrinkage pores,
ρ = liquid alloy density at the melting temperature in grams per cubic centimeter,
ν = quantity of the gas contained in the casting at standard temperature and pressure conditions (273 K at 1 atm) in cubic centimeters per 100 g of alloy, and
ν^* = solubility limit of gas in the solid at the solidus temperature at standard temperature and pressure conditions

Clamping Force

- it can be calculated from cavity pressure inside the mold and the sot projected area, on which this pressure is acting
- The clamping force is needed to compensate for the separating force developed when the metal is injected into the die. When the die is full, and the full pressure is developed, the separating force is
- $F = P * A$,
- where p is the pressure N/mm^2
- A is the projected area of the casting. mm^2
- Note that the answer will depend on whether the operation is hot- or cold-chamber, because pressures are higher in the cold-chamber than in the hot chamber process.

Die Casting In Summery

- **Process:** Molten metal is injected into closed metal dies under pressures ranging from 10 to 175 MPa .Pressure is maintained during solidification ,after which the dies separate and the casting is ejected along with its attached sprues and runners. Cores must be simple and retractable and take the form of moving metal segments.
- **Advantages**: Extremely smooth surfaces and excellent dimensional accuracy; rapid production rate; product tensile strengths as high as 415 MPa .
- **Limitations:** High initial die cost; limited to high-fluidity nonferrous metals ; part size is limited; porosity may be a problem; some scrap in sprues, runners, and flash, but this can be directly recycled.

Die Casting In Summery

- **<u>Common metals</u>** :Alloys of aluminum, zinc, magnesium ,and lead ; Al so possible with alloys of copper and tin.
- **<u>Size limits:</u>** Less than 30 grams up through about 7 kg most common.
- **<u>Thickness limits</u>**: As thin as 0.75 mm ,but generally less than 13 mm .
- **<u>Typical tolerances</u>**: Varies with metal being cast; typically 0.1mm for the first 2.5 cm (0.005 in. f or the first inch) and 0.02 mm for each additional centimeter
- **<u>Draft allowances</u>**: 1°–3°. Surface finish: 1–2.5 µm rms