CASTING PROCESS - 4

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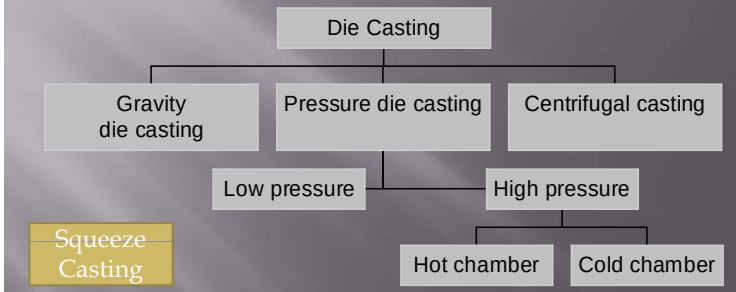
METAL CASTING PROCESSES

- Permanent Mold Casting Processes
  - Gravity die casting
  - Pressure die casting
    - Low pressure
    - High pressure
      - Hot chamber
      - Cold chamber
  - Centrifugal Casting
  - Squeeze Casting

Permanent Mold Casting Processes

- Economic disadvantage of expendable mold casting: a new mold is required for every casting
- In permanent mold casting, the mold is reused many times
- Problem however is to find a mould material that can withstand the melting point of the cast metal.
- Best for large quantities of precision parts in lower melting point alloys

Permanent mould casting



Advantages and Limitations of Permanent Mold Casting

- Advantages:
  - Good dimensional control and surface finish
  - More rapid solidification caused by the cold metal mold results in a finer grain structure, so stronger castings are produced
- Limitations:
  - Generally limited to metals of lower melting point
  - Simple part geometries compared to sand casting because of the need to open the mold
  - High cost of mold

Applications of Permanent Mold Casting

- Due to high mold cost, process is best suited to high volume production and can be automated accordingly
- Typical parts: automotive pistons, cylinder heads, connecting rods, pump bodies, and certain castings for aircraft and missiles
- Metals commonly cast: aluminum, magnesium, copper-based alloys, and cast iron

The Gravity Die Casting Process

- Simplest of the die casting processes
- Uses a metal mold constructed of two sections designed for easy, precise opening and closing
- Molds used for casting lower melting point alloys are commonly made of steel or cast iron
- Molds used for casting steel must be made of refractory material, due to the very high pouring temperatures
- Materials
  - Usually non-ferrous metals,
  - for example: copper, aluminium, magnesium, but sometimes iron, lead, nickel, tin and zinc alloys.
  - Carbon steel can be cast with graphite dies.

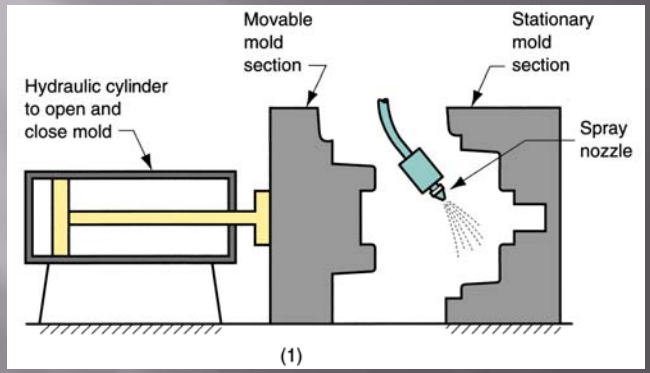


Figure 11.10 - Steps in permanent mold casting: (1) mold is preheated and coated

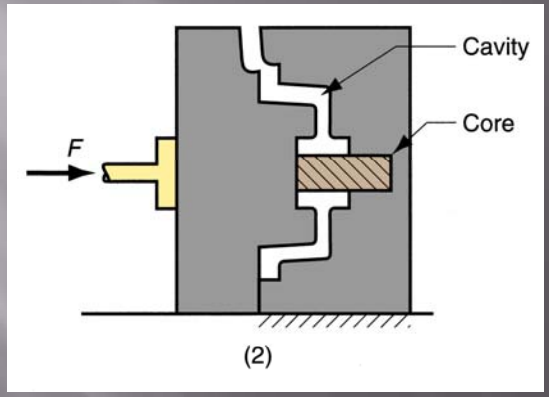


Figure 11.10 - Steps in permanent mold casting: (2) cores (if used) are inserted and mold is closed

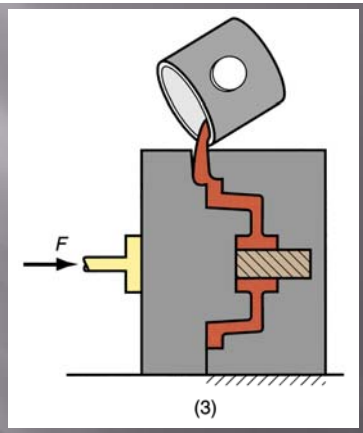
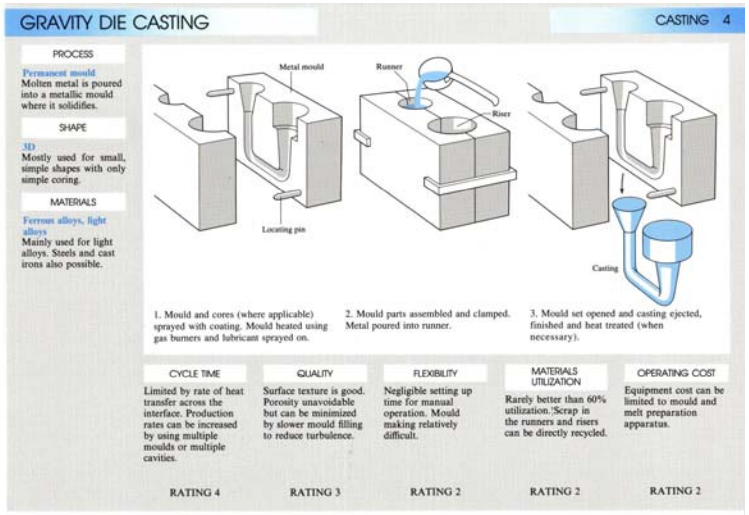
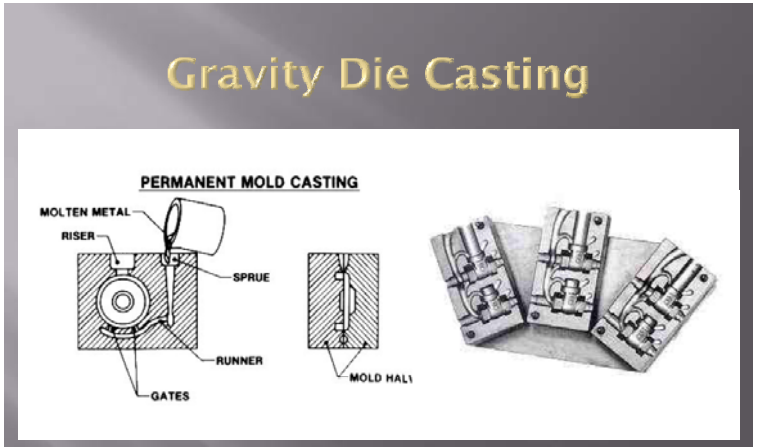


Figure 11.10 - Steps in permanent mold casting: (3) molten metal is poured into the mold





Gravity die casting-Economic considerations

- Production rates of 5-100 pieces/hour common, but dependent on size.
- Lead times can be many weeks.
- Material utilization is high.
- There is little scrap generated.
- If accuracy and surface finish is not an issue, can use sand cores instead of metallic or graphite for greater economy.

Gravity die casting - Design Aspects

- Shape complexity limited by that obtained in die halves.
- Undercuts are possible with large added cost.
- Inserts are possible with small added cost.
- Machining allowances in the range from 0.8 to 1.5 mm.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Draft angle ranges from 0.1º to 3º.
- Maximum section = 50 mm.
- Minimum section = 2 mm.
- Sizes range from 100 g to 300 kg in weight. Commonly used for castings <5 kg.

Gravity die casting - Quality issues

- Little porosity and inclusions.
- Redressing of the dies may be required after several thousand castings.
- Collapsible cores improve extraction difficulties on cooling.
- 'Chilling' effect of cold metallic dies on the surface of the solidifying metals needs to be controlled by pre-heating at correct temperature.
- Large castings sometimes require that the die is tilted as molten metal is being poured in to reduce turbulence.
- Mechanical properties are fair to good.

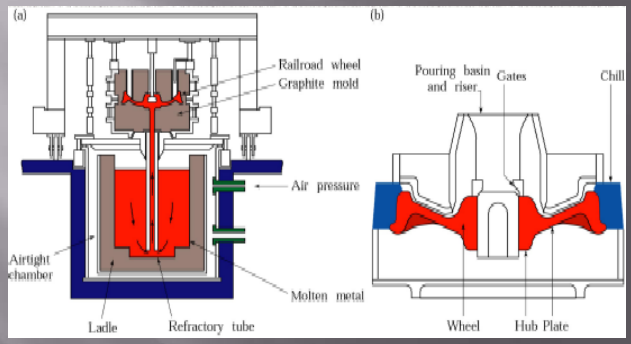
Gravity die casting - Quality issues

- Surface detail good.
- Surface roughness in the range 0.8 to 6.3 μm R_a can be achieved.
- Process capability charts showing the achievable dimensional tolerances using various materials are given on the next page. Allowances of ±0.25 to ±0.75 mm should be added for dimensions across the parting line.

Low Pressure Casting

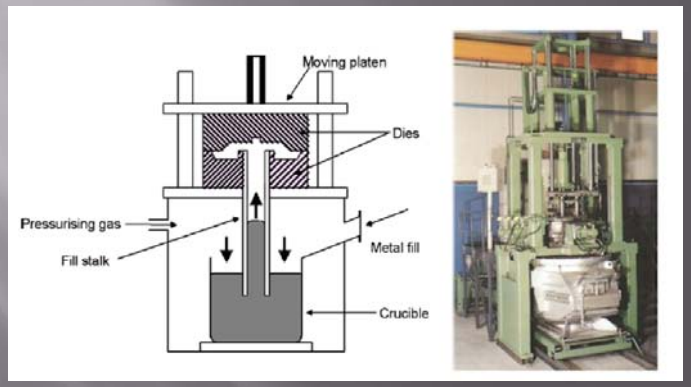
- Used a graphite or metal mold
- Molten metal is forced into the mold by gas pressure
- The pressure is maintained until the metal solidifies in the mold
- Used for high-quality castings

Low Pressure Casting



(a) The bottom-pressure casting process utilizes graphite molds for the productin of steel railroad wheels. (b) Gravity pouring method of casting a railroad wheel. Note that the pouring basin also serves as a riser.

Low Pressure Casting



Pressure Die Casting

- A permanent mold casting process in which molten metal is injected into mold cavity under high pressure
- Pressure is maintained during solidification, then mold is opened and part is removed
- Molds in this casting operation are called *dies*; hence the name die casting
- Use of high pressure to force metal into die cavity is what distinguishes this from other permanent mold processes

Die Casting Machines

- Designed to hold and accurately close two mold halves and keep them closed while liquid metal is forced into cavity
- Two main types:
  1. Hot-chamber machine
  2. Cold-chamber machine

Hot-Chamber Die Casting

- Metal is melted in a container, and a piston injects liquid metal under high pressure into the die
- High production rates - 500 parts per hour not uncommon
- Applications limited to low melting-point metals that do not chemically attack plunger and other mechanical components
- Casting metals: zinc, tin, lead, and magnesium

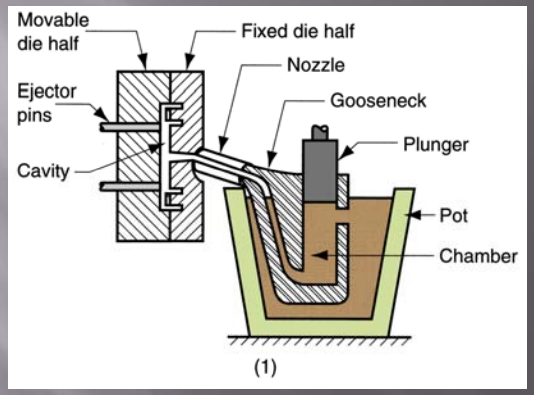


Figure 11.13 - Cycle in hot-chamber casting:
(1) with die closed and plunger withdrawn, molten metal flows into the chamber

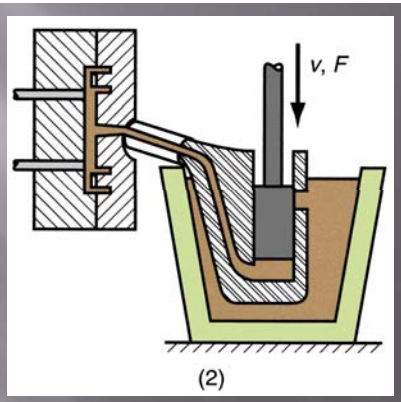


Figure 11.13 - Cycle in hot-chamber casting:
(2) plunger forces metal in chamber to flow into die, maintaining pressure during cooling and solidification

Cold-Chamber Die Casting Machine

- Molten metal is poured into unheated chamber from external melting container, and a piston injects metal under high pressure into die cavity
- High production but not usually as fast as hot-chamber machines because of pouring step
- Casting metals: aluminum, brass, and magnesium alloys
- Advantages of hot-chamber process favor its use on low melting-point alloys (zinc, tin, lead)

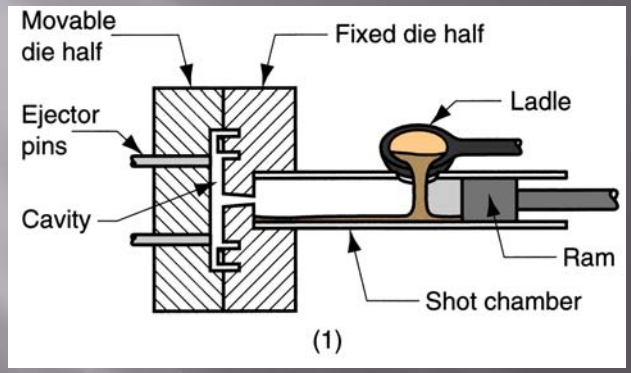


Figure 11.14 - Cycle in cold-chamber casting:
(1)with die closed and ram withdrawn, molten metal is poured into the chamber

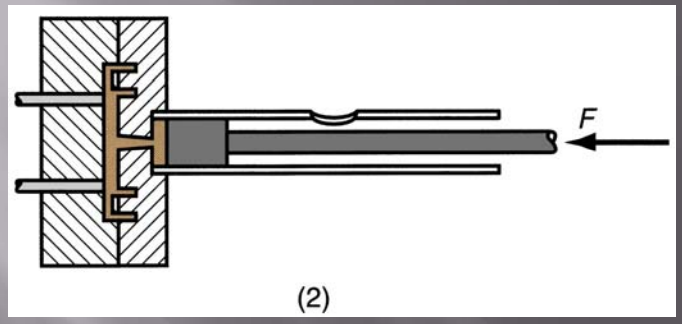


Figure 11.14 - Cycle in cold-chamber casting:
(2) ram forces metal to flow into die, maintaining pressure during cooling and solidification

Pressure die casting

- Materials
  - Limited to non-ferrous metals, i.e. zinc, aluminium, magnesium, lead, tin and copper alloys.
  - Zinc and aluminium alloys tend to be the most popular.
  - High temperature metals, e.g. copper alloys, reduce die life.
  - Iron based materials for casting are under development.

Pressure die casting - Economics

- Production quantities of >10,000 are economical.
- Tooling costs are high.
- Equipment costs are high.
- Direct labour costs are low to moderate.
- Finishing costs are low. Little more than trimming operations required to remove flash, etc.

Pressure die casting - Applications

- Transmission cases.
- Engine parts.
- Pump components.
- Electrical boxes,
- Domestic appliances.
- Toy parts.

Pressure die casting - Design aspects

- Shape complexity can be high. Limited by design of movable cores.
- Bosses are possible with added costs.
- Undercuts and inserts are possible with added costs and reduced production rates.
- Wall thickness should be as uniform as possible; transitions should be gradual.
- Sharp corners, or corners without proper radii should be avoided. (Pressure die casting permits smaller radii because metal flow is aided.)
- Placing of parting line important, i.e. avoid placement across critical dimensions.

Pressure die casting - Design aspects

- Holes perpendicular to the parting line can be cast.
- Casting holes for subsequent tapping is generally more economical than drilling.
- Machining allowance is normally in the range from 0.25 to 0.8 mm.
- Draft angle ranges from 0.5 to 3º.
- Maximum section = 12 mm.
- Minimum section ranges from 0.4 to 1.5 mm depending on material used.
- Sizes range from 10 g to 50 kg. Castings up to 100 kg have been made in zinc. Copper, tin and lead castings are normally less than 5 kg.

Pressure die casting - Quality Issues

- Very low porosity.
- Particularly suited where casting requires high mechanical properties or absence of creep.
- The high melting temperature of some metals can cause significant processing difficulties and die wear.
- Difficulty is experienced in obtaining sound castings in the larger capacities due to gas entrapment.
- Close control of temperature, pressure and cooling times important in obtaining consistent quality castings.
- Mechanical properties are good.

Pressure die casting - Quality Issues

- Surface detail excellent.
- Surface roughness in the range 0.4 to 3.2 μm R_a can be achieved.
- Process capability charts showing the achievable dimensional tolerances using various materials are given below. Allowances of ±0.05 to ±0.35 mm should be added for dimensions across the parting line.

Molds for Die Casting

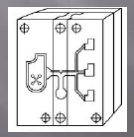
- Usually made of tool steel, mold steel, or maraging steel
- Tungsten and molybdenum (good refractory qualities) used to die cast steel and cast iron
- Ejector pins required to remove part from die when it opens
- Lubricants must be sprayed into cavities to prevent sticking

Various types of cavities in a die casting die.

a) Single – cavity die

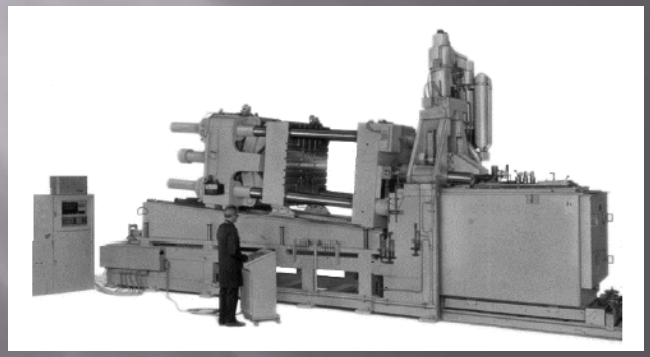
b) Multiple – cavity die

c) Combination die

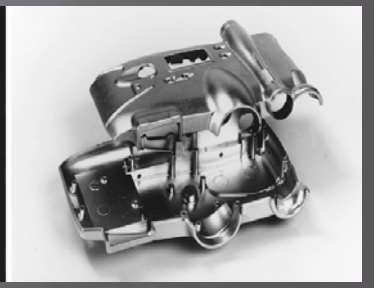


d) Unit die

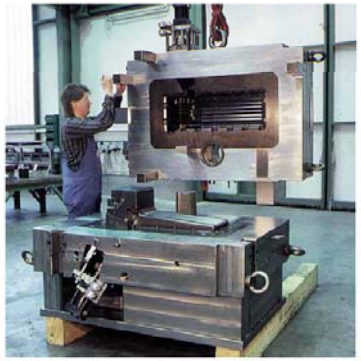
800 ton hot chamber die casting machine, DAM 8005. This is the largest hot chamber machine in the world and costs about $1.25 million.



Die Casting Parts



Example of application - diecasting: Truck oil pan and die



source: Härer-Werkzeugbau

Example of application - diecasting: Gear case and converter

gear case
material: aluminium diecasting AlSi9Cu3
weight: 5.4 kg

Torque converter housing HP500, ZF
material: aluminium diecasting AlSi9Cu3
dimensions: 542 x 553 x 553 mm
wall thickness: 3,5 - 25 mm
weight: 41,0 kg

source: (1) Georg Fischer, Herzogenburg, (2) Honsel

Advantages and Limitations of Die Casting

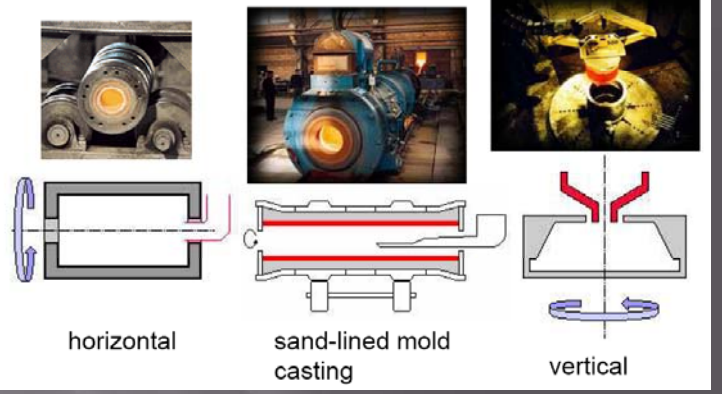
- Advantages:
  - Economical for large production quantities
  - Good dimensional accuracy and surface finish
  - Thin sections are possible
  - Rapid cooling provides small grain size and good strength to casting
- Disadvantages:
  - Generally limited to metals with low metal points
  - Part geometry must allow removal from die cavity

Centrifugal Casting

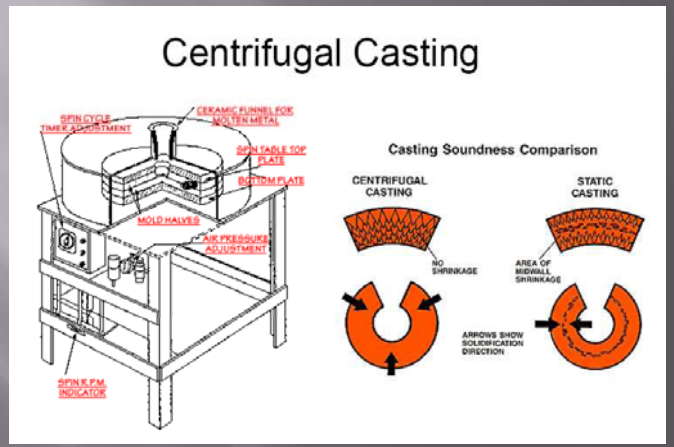
A group of casting processes in which the mold is rotated at high speed so centrifugal force distributes molten metal to outer regions of die cavity

- The group includes:
  - True centrifugal casting
  - Semicentrifugal casting
  - Centrifuge casting

Centrifugal Casting



Centrifugal Casting



True Centrifugal Casting

- Molten metal is poured into rotating mold to produce a tubular part
- In some operations, mold rotation commences after pouring rather than before
- Parts: pipes, tubes, bushings, and rings
- Outside shape of casting can be round, octagonal, hexagonal, etc., but inside shape is (theoretically) perfectly round, due to radially symmetric forces

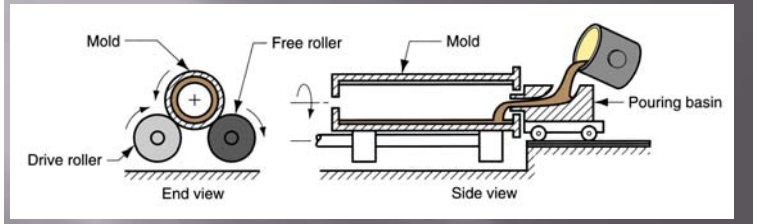
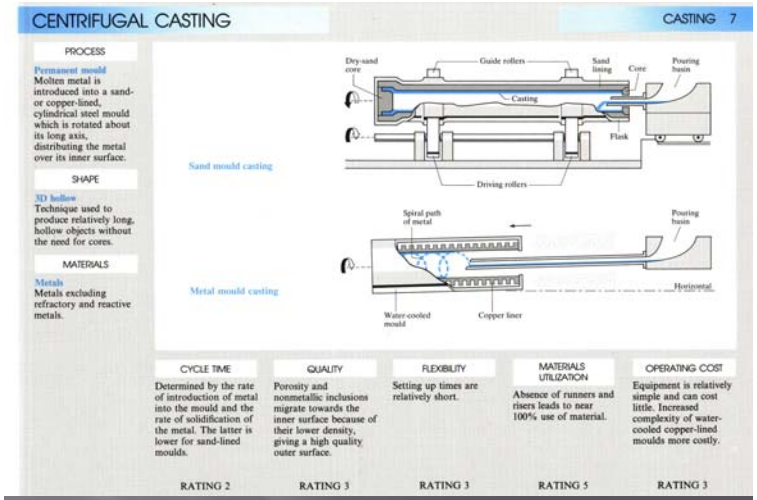
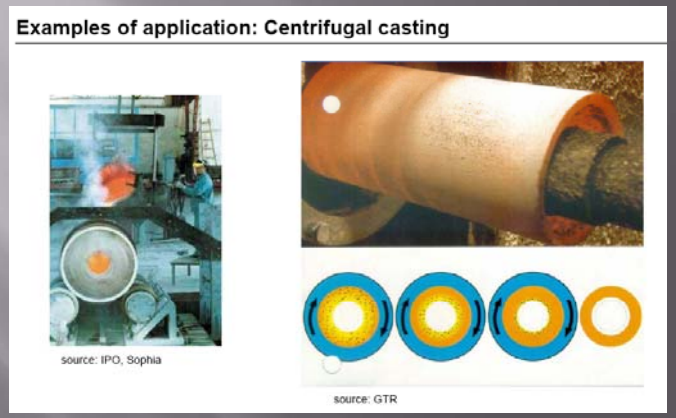
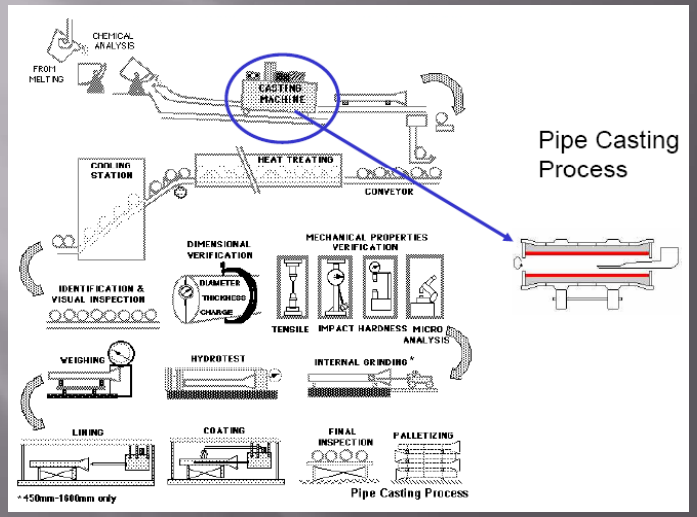


Figure 11.15 - Setup for true centrifugal casting

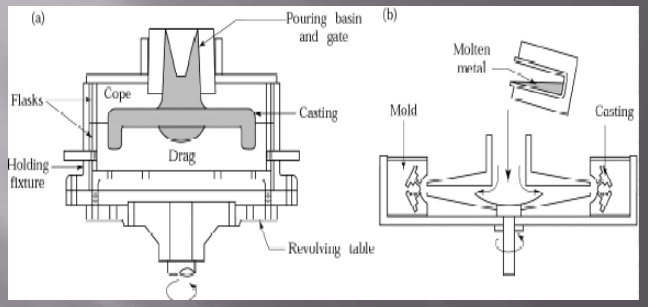






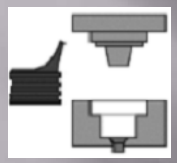
Pipe Casting Process

Semi centrifugal Casting Process

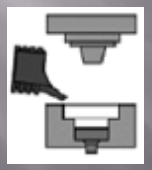


(a) Schematic illustration of the semi centrifugal casting process. Wheels with spokes can be cast by this process. (b) Schematic illustration of casting by centrifuging. The molds are placed at the periphery of the machine, and the molten metal is forced into the molds by centrifugal force.

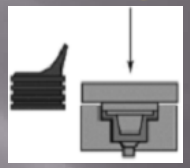
Squeeze Casting Process



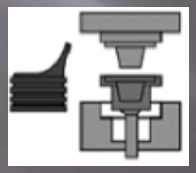
(a) Melt Metal



(b) Pour molten metal into die



(c) Close die and apply pressure



(d) Eject squeeze casting and charge melt stock and repeat cycle

Sequence of operations in the squeeze-casting process. This process combines the advantages of casting and forging.