ME 333

Manufacturing Processes II

Chapter 3

Special Casting Processes

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- The process used for making a casting depends upon **the quantity to be produced, the metal to be cast,** and **the complexity of part**.
- Sand molds are single-purpose molds, and are completely destroyed after the metal has solidified. Obviously, **use of a permanent mold** provides considerable saving in labor cost.
- **Permanent molds** must be made of metals capable of withstanding high temperatures.
- Due to high cost, they are recommended only when many castings are to be produced.
- Although permanent molds are impractical for large castings and alloys of high melting temperatures, they can be used advantageously for small and medium-sized castings that are manufactured in large quantities.
- A summary of various special casting methods to be discussed in this chapter is as follows:
  - **Die Casting**
  - **Centrifugal & Semi-Centrifugal Casting**
  - **Investment (Precision or Lost-Wax) Casting**
  - **Continuous Casting**
  - **Shell Molding**

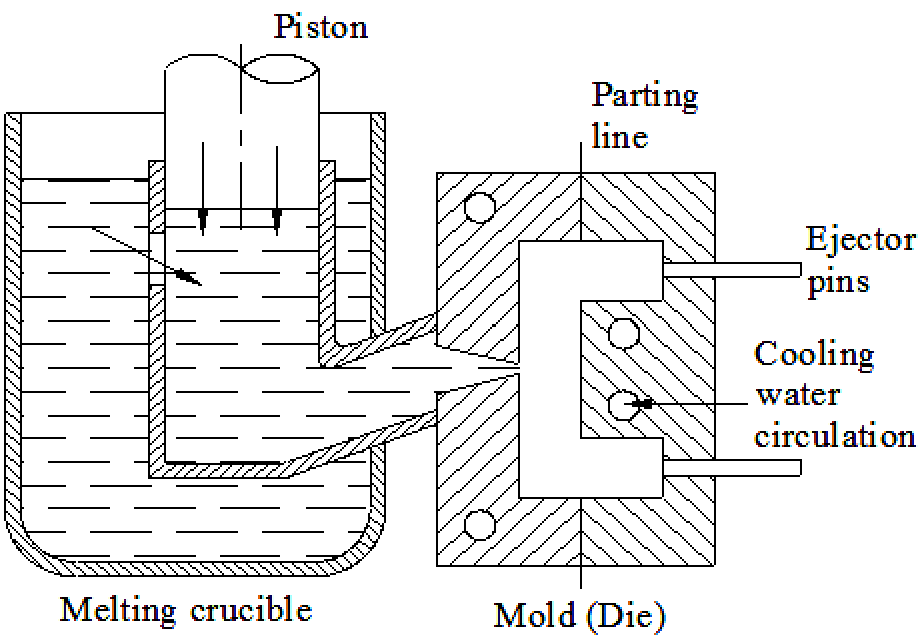
- In this process, molten metal is forced by pressure into a metal mold (known as **die**).
- The usual pressure is **from 100 to 125 atm**.
- It is **the most widely used method** of permanent mold processes.
- There are two methods employed:

  1. Cold-chamber die casting

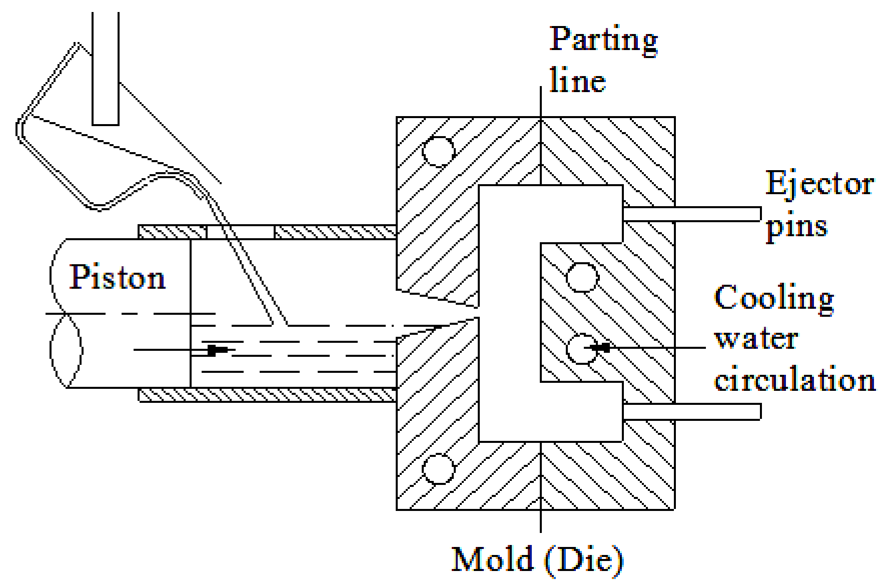
  2. Hot-chamber die casting

1. **Cold-chamber die casting:** Material to be cast is molten outside the machine. Used for metals of high melting temp. **(above 550 °C)** such as brass, aluminum, and magnesium.
2. **Hot-chamber die casting:** Materials to be cast is molten inside the machine. Used for metals of low melting temp. **(below 550 °C)** such as zinc, tin, and lead.

- The main distinction is determined by **the location of melting pot**. In hot-chamber, the pot is included in the machine whereas the pot is separate from the machine in cold-chamber (i.e. metal is introduced into injection cylinder by other means).



Hot-Chamber Die Casting



Cold-Chamber Die Casting

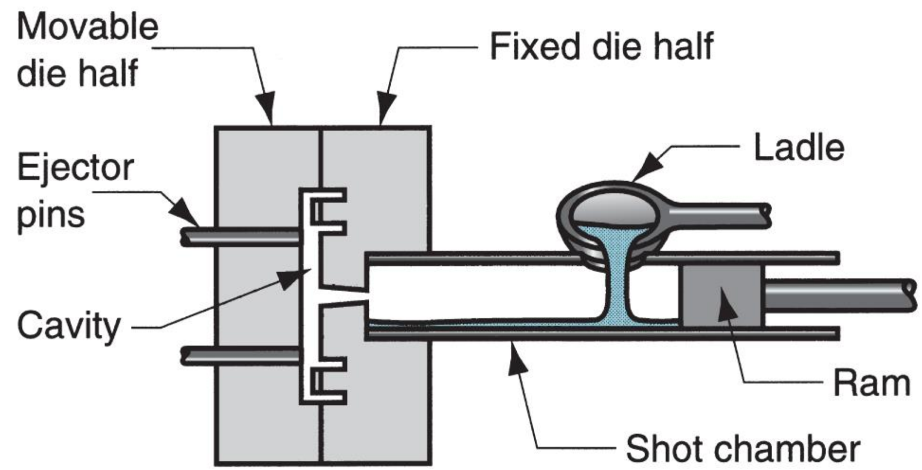
Cold-Chamber Die Casting

Cycle in cold-chamber die casting:

1. With die closed and ram withdrawn, molten metal is poured into the chamber.

2. Ram forces the metal to flow into die, maintaining pressure during cooling and solidification.

3. Ram is withdrawn, die is opened, and the part is ejected.



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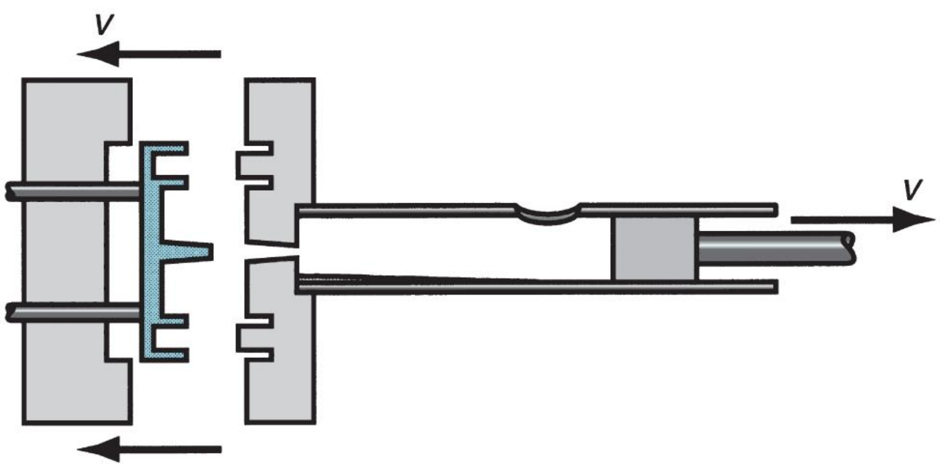

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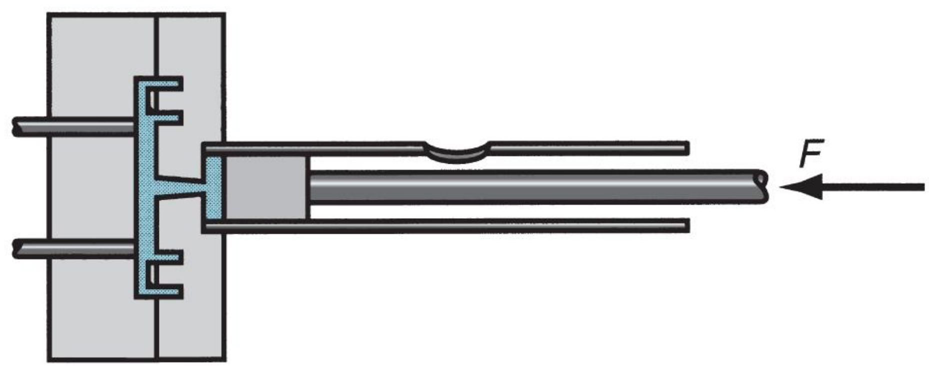

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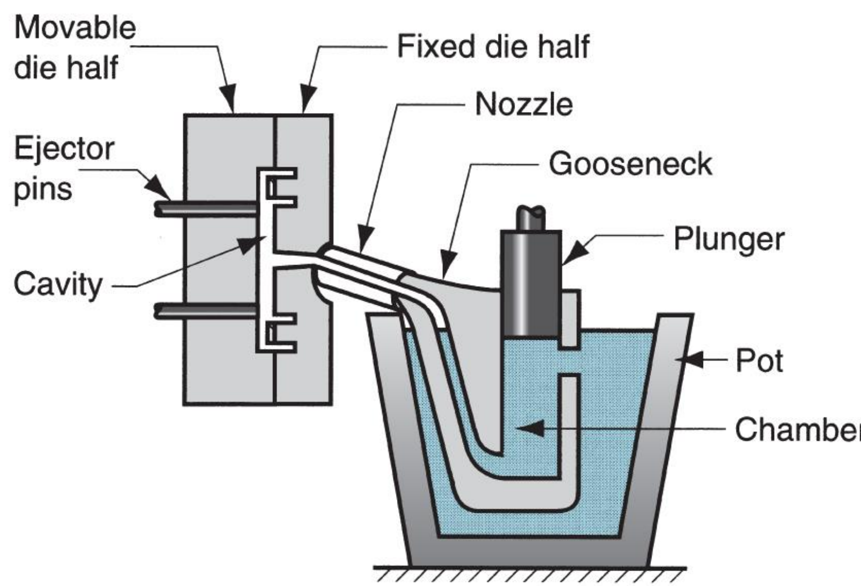
Hot-Chamber Die Casting

Cycle in hot-chamber die casting:

1. With die closed and plunger withdrawn, molten metal flows into the chamber.
2. Plunger forces the metal to flow into die, maintaining pressure during cooling and solidification.
3. Plunger is withdrawn, die is opened, and the part is ejected.



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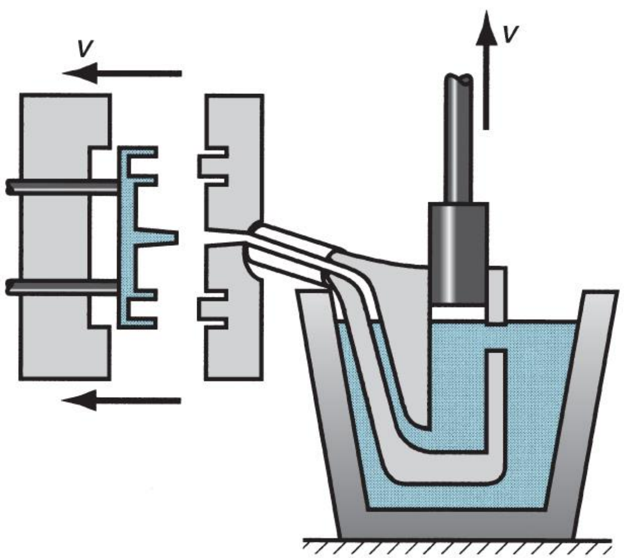

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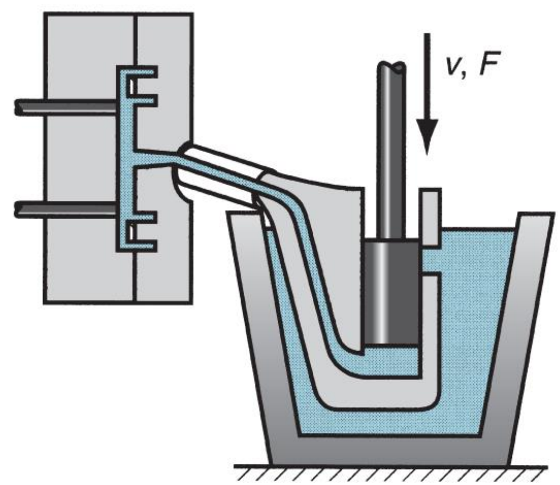

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Advantages:

☺ **Rapid process** (since both dies and cores are permanent)

☺ **Good surface quality** (smooth surface improves appearance and reduces work required for other operations)

☺ **Good dimensional tolerances** as compared to sand casting (the size is so accurately controlled that little or no machining is necessary)

☺ **Low scrap loss** (since sprue, runners, and gates can be remelted)

Disadvantages:

☹ **Shape restriction** (part geometry must allow for removal from die cavity)

Production quantities and materials in die casting:

➤ **The optimum production quantity** ranges from 1,000 to 200,000 pieces.

➤ **Maximum weight** of die castings are about 2 kg for brass and over 50 kg for aluminum.

➤ Small to medium size castings can be made at **cycle rates** of 100 to 800 die fillings per hour.

➤ **Die life** depends on metal cast, ranging from 10,000 fillings (brass) to several million (zinc).

➤ **single-cavity die** (big & complex parts) or **multiple-cavity die** (small parts in large quantity).

- Wide range of nonferrous alloys can be die-cast.
- The principal base metals are: **zinc**, **aluminum**, **magnesium**, **copper**, **lead**, **tin**
- They are classified in two groups:
  1. **Low-temperature alloys** (casting temp. below 550 °C)
  2. **High-temperature alloys** (casting temp. above 550 °C)

Zinc-Base Alloys

- **Over 75% of die castings** are produced from zinc-base alloys.
- Melting point is **around 400 °C**, thus they are cast by hot-chamber die casting.
- Alloying elements: **Aluminum** improves mechanical properties; **copper** improves tensile strength and ductility; **magnesium** makes casting stable in microstructure.
- Zinc-base alloys are widely used in: automotive industry, washing machines, refrigerators, business machines, etc.

ASTM No.	Al	Cu	Mg	Zn
AG40A(XXIII)	4.1	0.1 (max)	0.04	Remainder
AC41A(XXV)	4.1	1.0	0.04	Remainder

Aluminum-Base Alloys

- They are preferred due to their lightness in mass and resistance to corrosion.
- Compared to zinc alloys, they are more difficult to cast (melting point of **around 550 °C**).
- Molten aluminum will attack steel if kept in continuous contact, so **cold-chamber process** generally is used.
- Alloying elements: **Silicon** increases hardness and corrosion resistance; **copper** increases mechanical properties; **magnesium** increases lightness and resistance to impact.
- They are generally used in: aerospace industry and production of pistons.

ASTM No.	Cu	Si	Mg	Al	Uses
S12A&B	-	12	-	Rem.	Large intricate castings
S5C	-	5	-	Rem.	General purpose
G8A	3	-	8	Rem.	High strength, corrosion resistance
SG100A&B	-	9.5	0.5	Rem.	General purpose, excellent casting characteristics
SC84B	3.5	9	-	Rem.	Good machinability and castability

Copper-Base Alloys

- Die casting of **brass** and **bronze** present greater problems due to their high casting temp. **(around 870 to 1040 °C)**, which needs heat-resisting die material.
- Copper alloys are **cold chamber die-cast**.
- They have extensive use in: miscellaneous hardware, electric-machinery parts, small gears, marine, automotive and aircraft fittings, chemical apparatus, and other small parts.

ASTM No.	Cu	Si	Sn	Pb	Zn	Uses
Z30A	57 (min)	-	1.5	1.5	30 (min)	Yellow brass, good machinability
Z5331A	65	1	-	-	Rem.	General purpose, corrosion res., good castability
Z5144A	81	4	-	-	Rem.	High strength, hardness, wear res., difficult to mold

Magnesium-Base Alloys

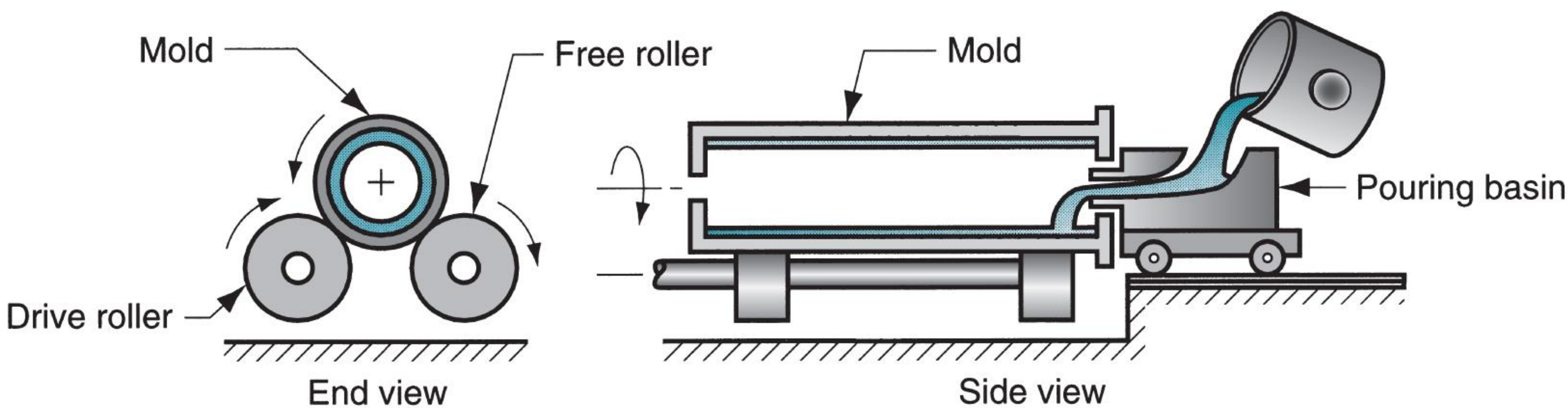
- Mainly alloyed with aluminum, containing small amounts of other elements.
- They have the lowest density.
- **Cold-chamber die casting** is suitable (casting temp. is **around 670-700 °C**).

ASTM No.	Al	Zn	Mn	Si	Cu	Ni	Mg
B94	9	0.5	0.13	0.5	0.3	0.03	Rem.

- It is a process of **rotating the mold** while the metal solidifies so as **to utilize centrifugal force** to position the metal in the mold.

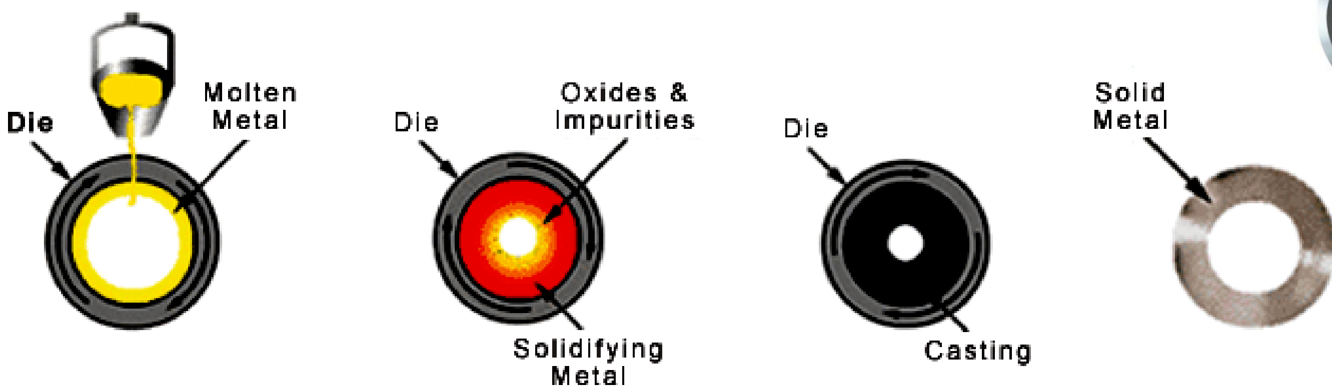
- **Castings of symmetrical shapes** are naturally suitable for this method, although many other types of castings can be produced.

- It is often more economical than other methods. Cores in cylindrical shapes and risers or feed-heads are eliminated. The castings have a dense metal structure with all impurities forced back to the centre where frequently they can be machined out.

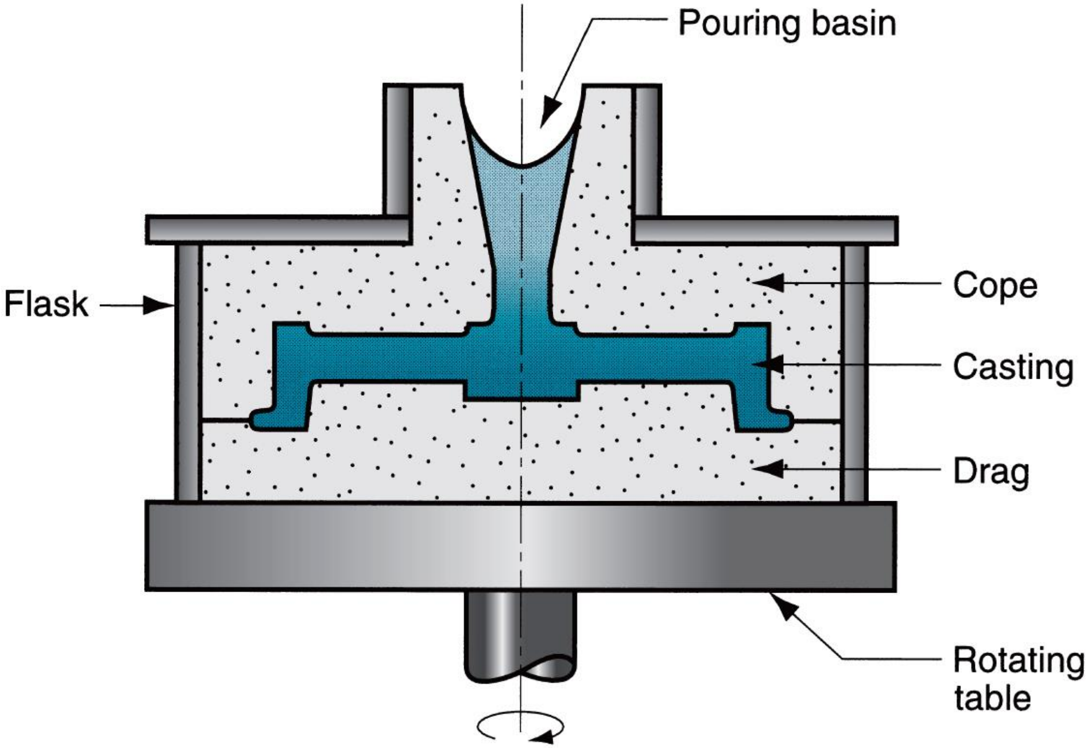


- Piston rings (50-100 grams) to paper mill rolls (over 42 tons) have been cast in this manner. Aluminum engine block uses centrifugally cast iron liners.

- In casting of some alloys, the heavier elements tend to be separated from the base metal, which is known as **gravity segregation**. The metal is forced against walls on the mold with a centrifugal force of approximately 70 g, which is 70 times greater force than the force of gravity alone on the casting. Forces as high as 150 g have also been used, but they are unnecessary unless very thick-walled cylinders are being cast.



- In this method, centrifugal force is used to produce **solid castings rather than tubular parts**.
- **Density of metal in the final casting** is greater in the outer sections than at the center of rotation.
- The process is used on parts in which center of the casting is machined away (such as wheels and pulleys).



- **Very smooth, highly accurate castings** can be made from ferrous and nonferrous alloys.
- Useful in casting of **unmachinable alloys and radioactive metals**.
- There are a number of processes employed, but all of them incorporate sand, ceramic, plaster (*alçı*), or plastic shell made from an accurate pattern into which metal is poured.
- Patterns are produced from wax (*mum*) or plastics which are subsequently melted from mold, leaving a cavity having all the details of the original pattern.

Advantages:

☺ intricate forms with undercuts can be cast

☺ very smooth surface with no parting line

☺ dimensional accuracy is good

☺ unmachinable parts can be cast

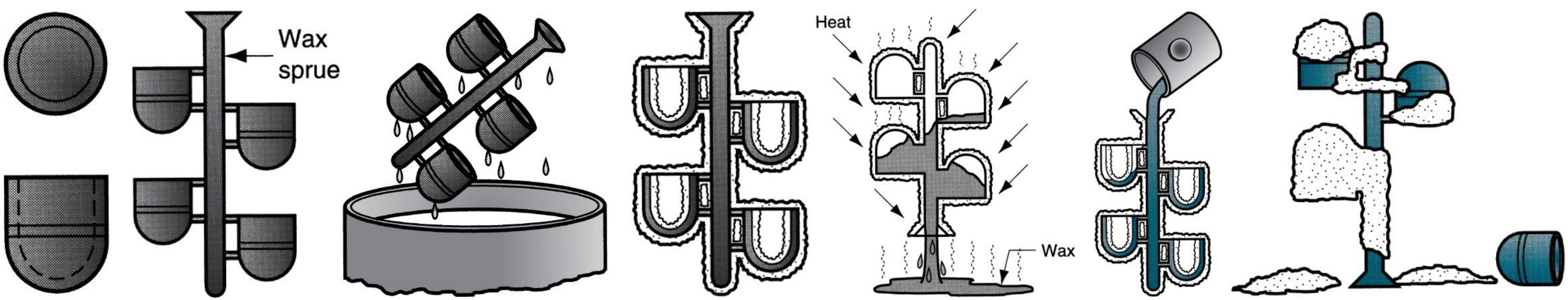
☺ may replace die casting for short runs

Disadvantages:

☹ expensive

☹ not suitable for big parts

1. First step requires **the exact replica** of the part to be cast (made from steel or brass). From this replica, **a split mold** (bismuth or lead-alloy) is made. After wax is poured into the mold and solidification takes place, the mold is opened and **the wax pattern** is removed.
2. Several patterns are **assembled together (wax tree)** with necessary gates and risers by heating the contact surfaces (wax welding) with a hot wire.
3. This cluster is **molded (coated)** by silica sand, plaster or ceramic slurries.
4. After the mold material gets sufficient strength, the mold is **placed upside down and heated** in an oven for several hours to melt out the wax and to dry the mold.
5. Casting can be produced **by gravity** *(as in figure)*, **vacuum**, **pressure** or **centrifugal force**.
6. When the solidification finished, the mold is broken away and gates with risers are cut-off.



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- It consists of pouring molten metal into one end of a metal mold (open at both ends), cooling rapidly, and extracting the solid product in a continuous length from the other end.
- **Copper, brass, bronze, aluminum, cast iron,** and **steel** can be cast.
- It is suitable for **any shapes of uniform cross-section** (round, square, rectangular, hexagonal, fluted, gear toothed, and many other forms; solid or hollow).

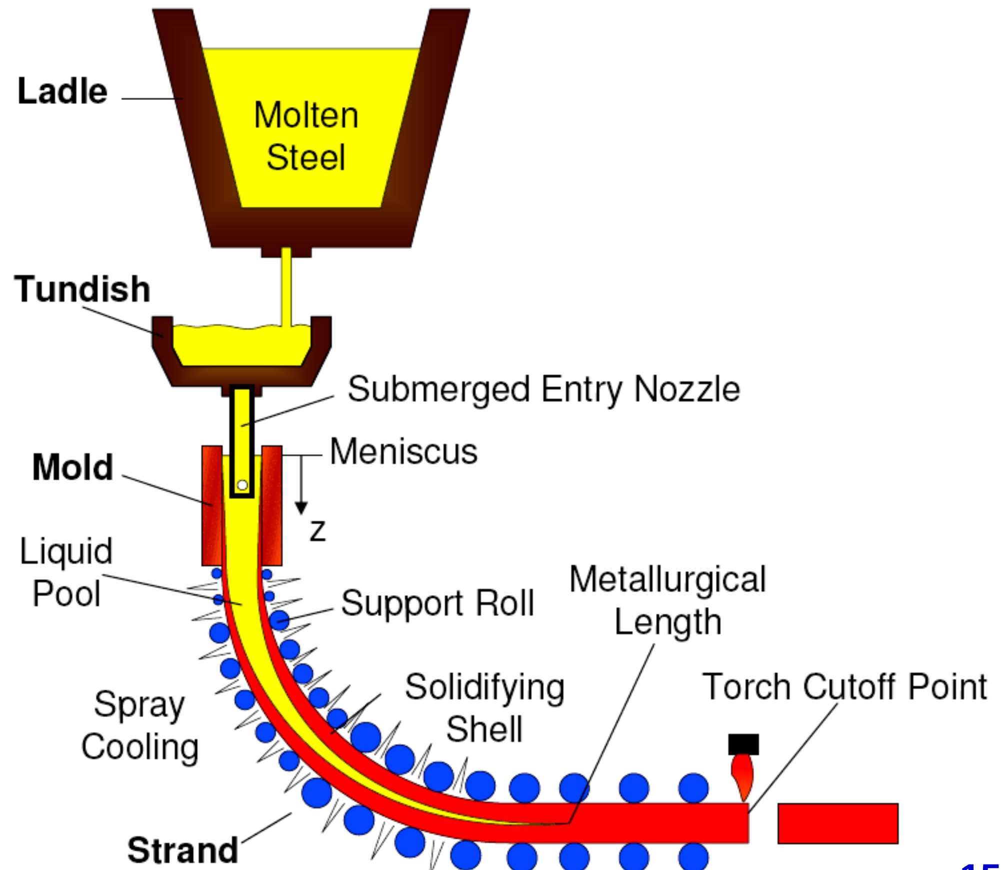
Advantages:

☺ It yields 10% more than rolling from ingots. Ingots have a porous end, which returns back to furnace. This waste is eliminated.

☺ A hollow center occurs from shrinkage during continuous casting, but it is welded shut after several rolling passes. Thus, continuous cast structure is more uniform and dense.

☺ Physical properties and surface finish are comparable to those obtained in other metal mold processes.

☺ The process is essentially automatic, and hence unit labor cost is low.



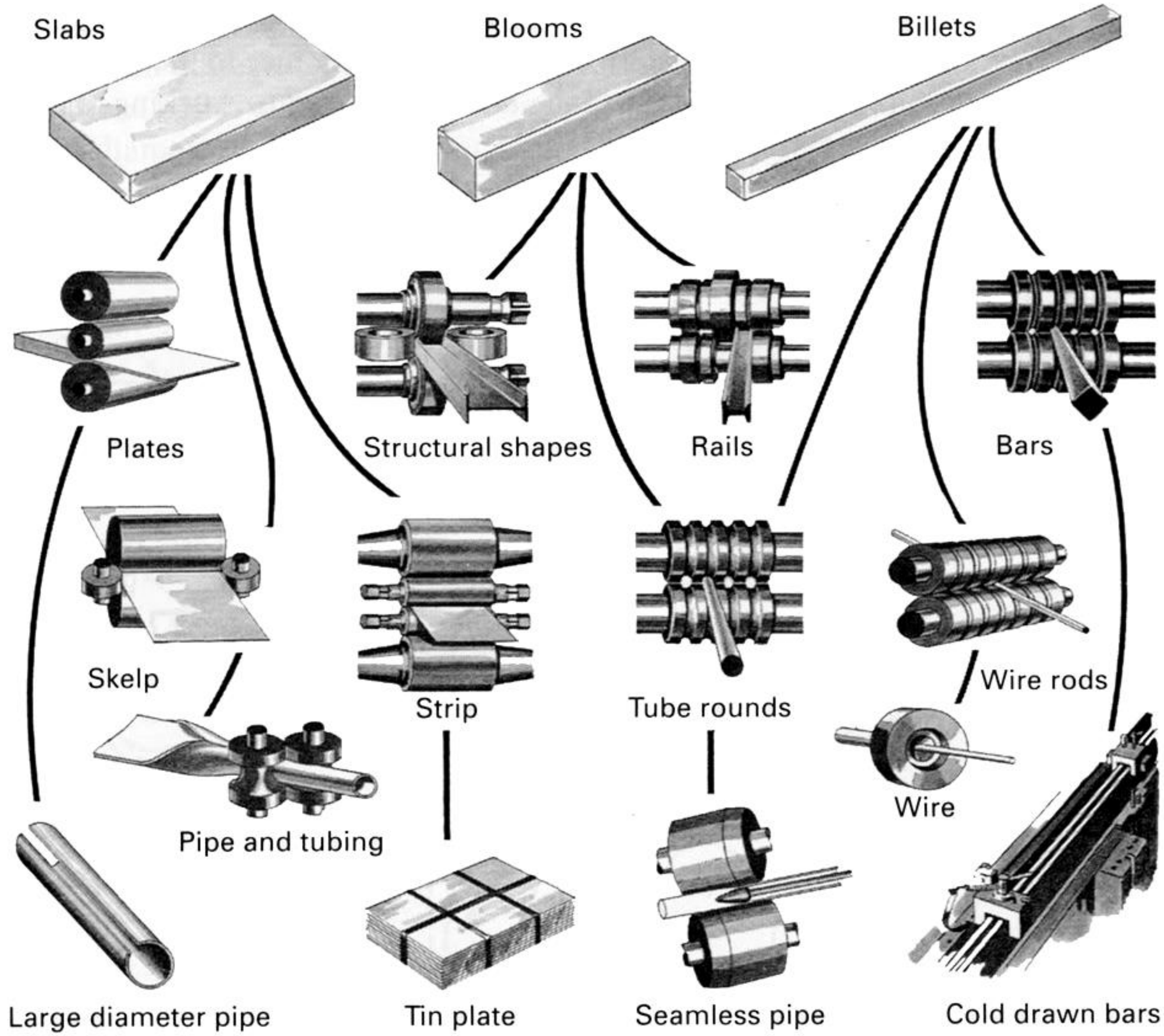
- A growing use is to produce **blooms, billets, slabs** for rolling structural shapes (cheaper than rolling from ingots).

- **A bloom** has square cross-section with min. size of 15 x 15 cm.

- **A billet** (smaller than bloom) has square cross-section from 4 cm up to the size of a bloom.

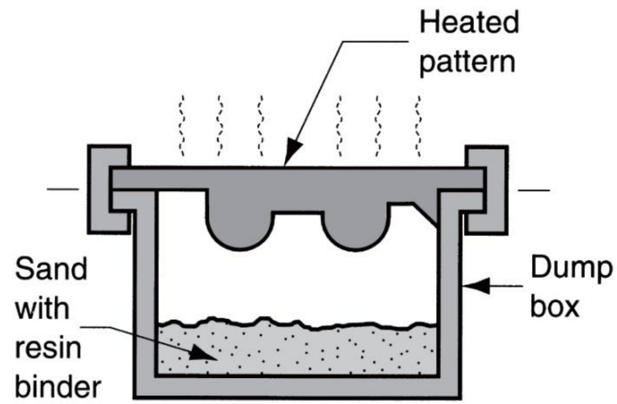
- **Slabs** with rectangular sections (min. 25 cm wide & 4 cm thick) are rolled from either ingot or bloom. The width is always 3 to 4 times the thickness. Plates, skelp and thin strips are rolled from slab.

- Other shapes are produced from slabs, blooms, and billets.



Shell Molding

1. **A metal pattern** is heated and placed over a box containing sand mixed with thermosetting resin.
2. **Box is inverted** so that sand and resin fall onto the hot pattern, causing a layer of hard shell.
3. **Box is repositioned** so that loose uncured particles drop away.
4. **Sand shell is heated** in oven for few minutes to complete curing.
5. Shell mold is **stripped** from pattern.
6. Two halves of shell mold are assembled, supported by sand or metal shot in a box, and **pouring is accomplished**.
7. **Finished casting** with sprue is removed.



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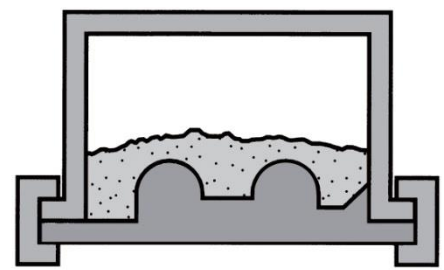
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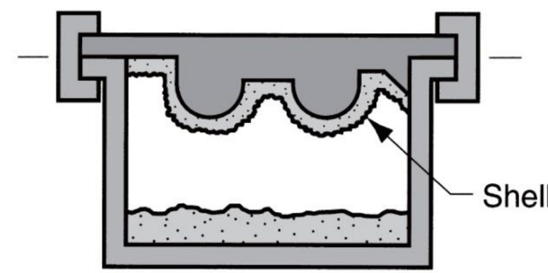

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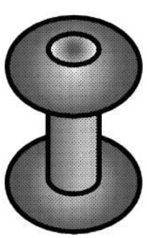
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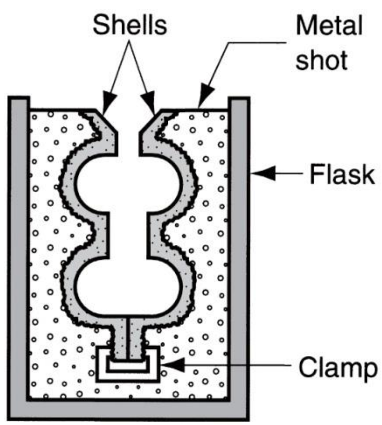

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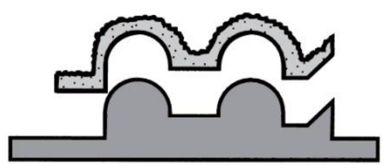
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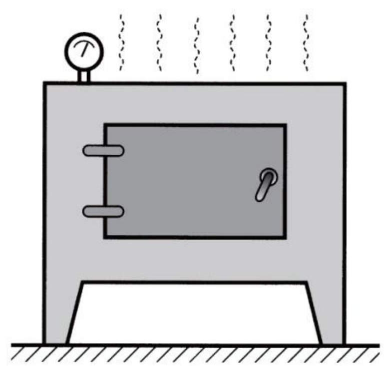
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Advantages:

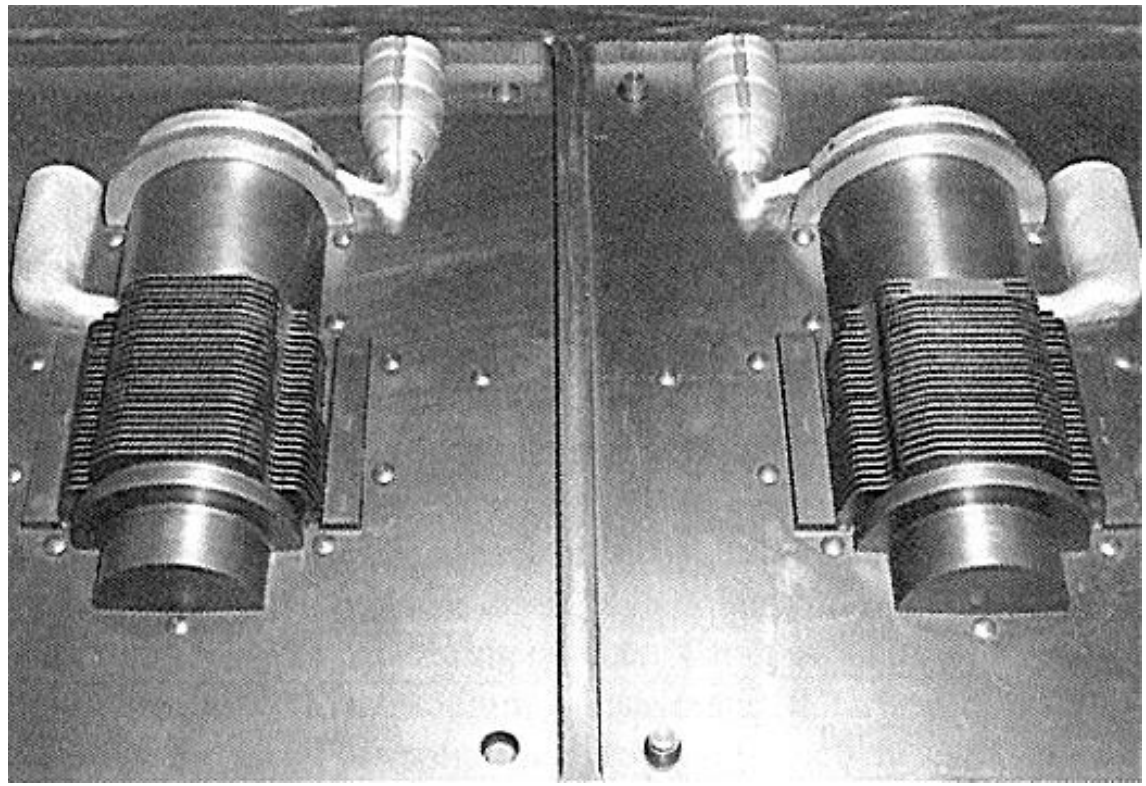
- ☺ Good surface finish (up to 2.5 μm)
- ☺ Good dimensional accuracy (± 0.25 mm)
- ☺ Suitable for mass production

Disadvantages:

- ☹ Expensive metal pattern

Application Area:

- ➤ Mass production of steel castings of less than 10 kg



Two halves of a shell mold pattern