Department of Materials Engineering
General Materials Branch

Fourth Class

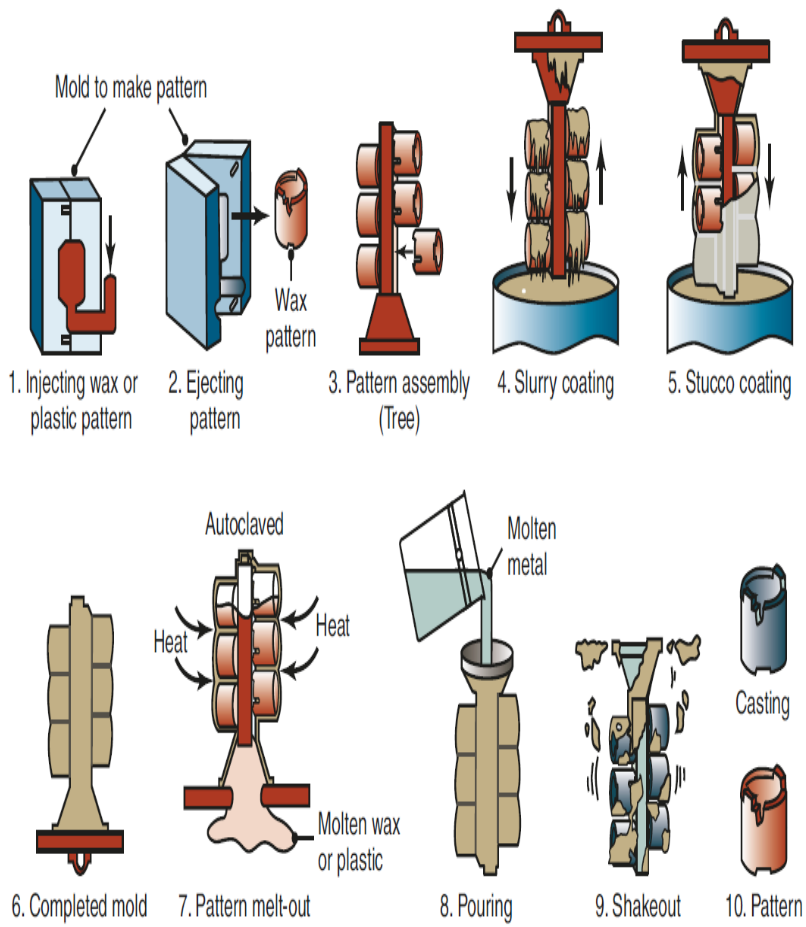
Casting Technology

Lecture Five :Investment and Single Crystal Casting

Class Code :ofp4npn

Investment casting

Investment Casting



1. *Produce a master pattern*
2. *From the master pattern, produce a master die*
3. *Produce wax patterns*
4. *Assemble the wax patterns onto a common wax sprue*
5. Coat the cluster or tree with a thin layer of investment material

Investment Casting

6. *Form additional investment around the coated cluster*
7. Allow the investment to fully harden
8. *Remove the wax pattern from the mold by melting or dissolving*
9. *Heat the mold in preparation for pouring*
10. *Pour the molten metal*
11. *Remove the solidified casting from the mold.*

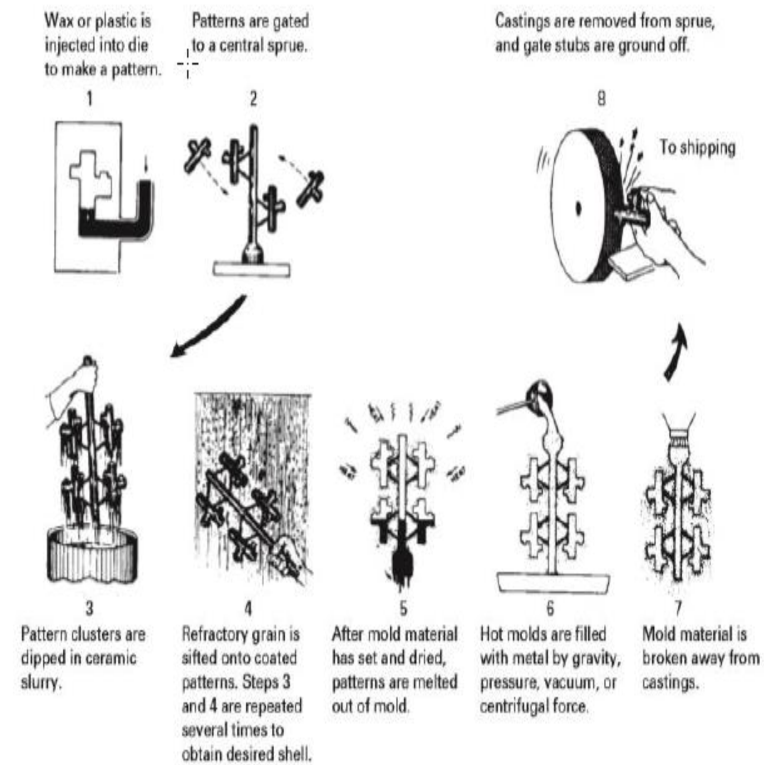


FIGURE 12-29 Investment-casting steps for the shell-casting procedure. *(Courtesy of Investment Casting Institute, Dallas, TX.)*

Investment Casting of Total Knee Replacements

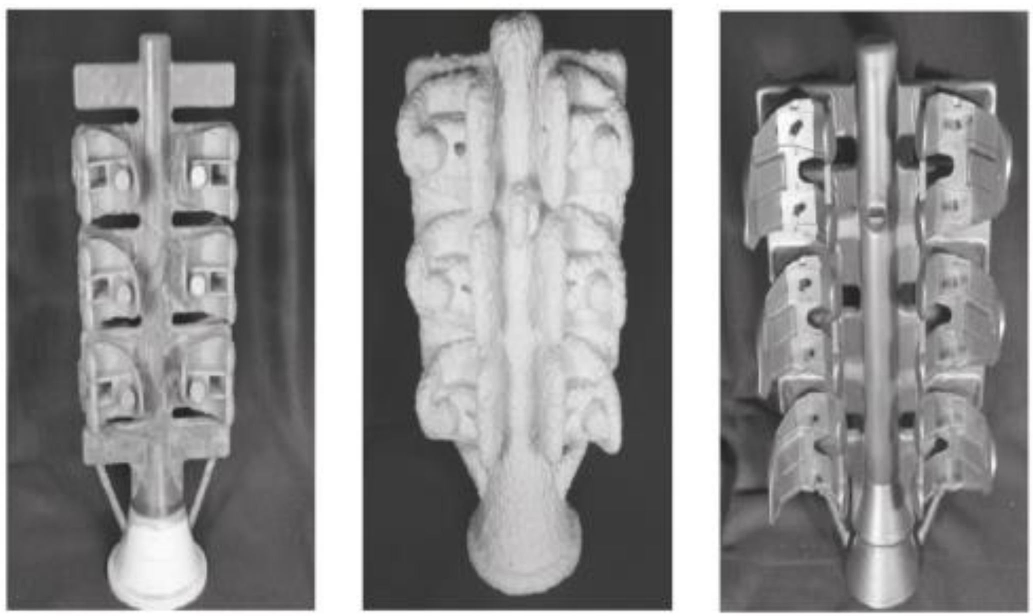
(a)

(b)

(c)

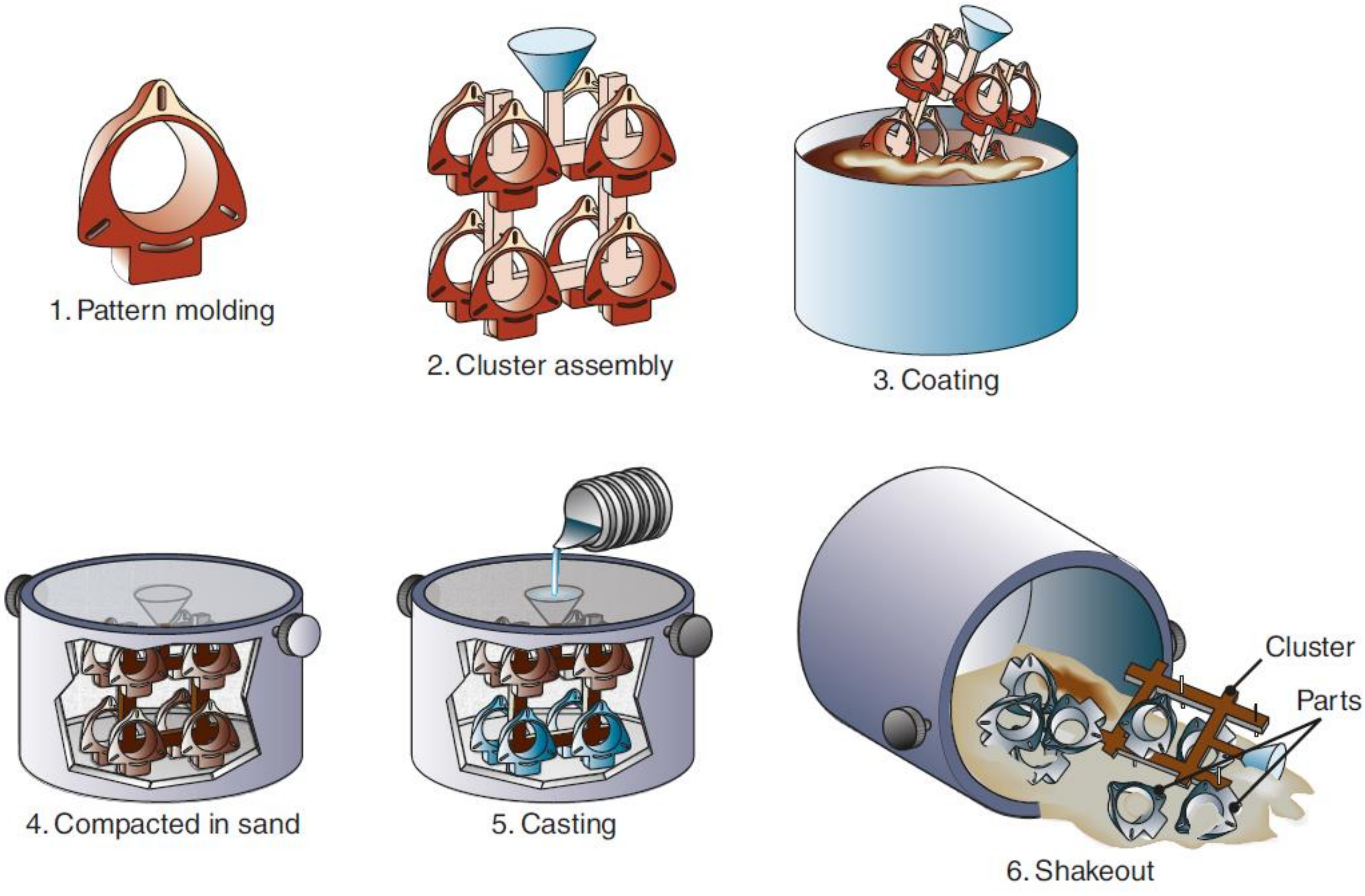
(d)

Investment Casting of Total Knee Replacements

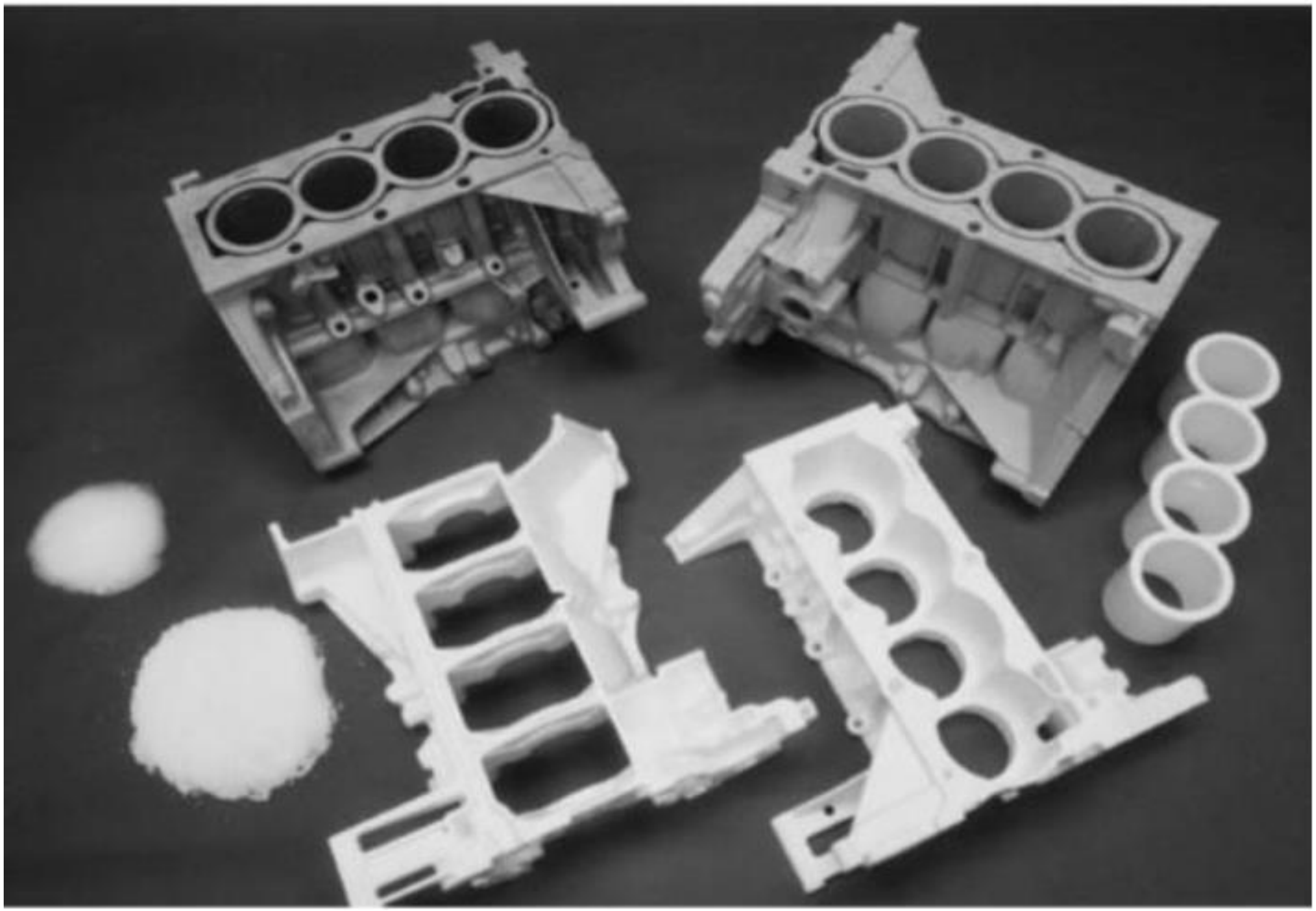


(a) (b) (c)

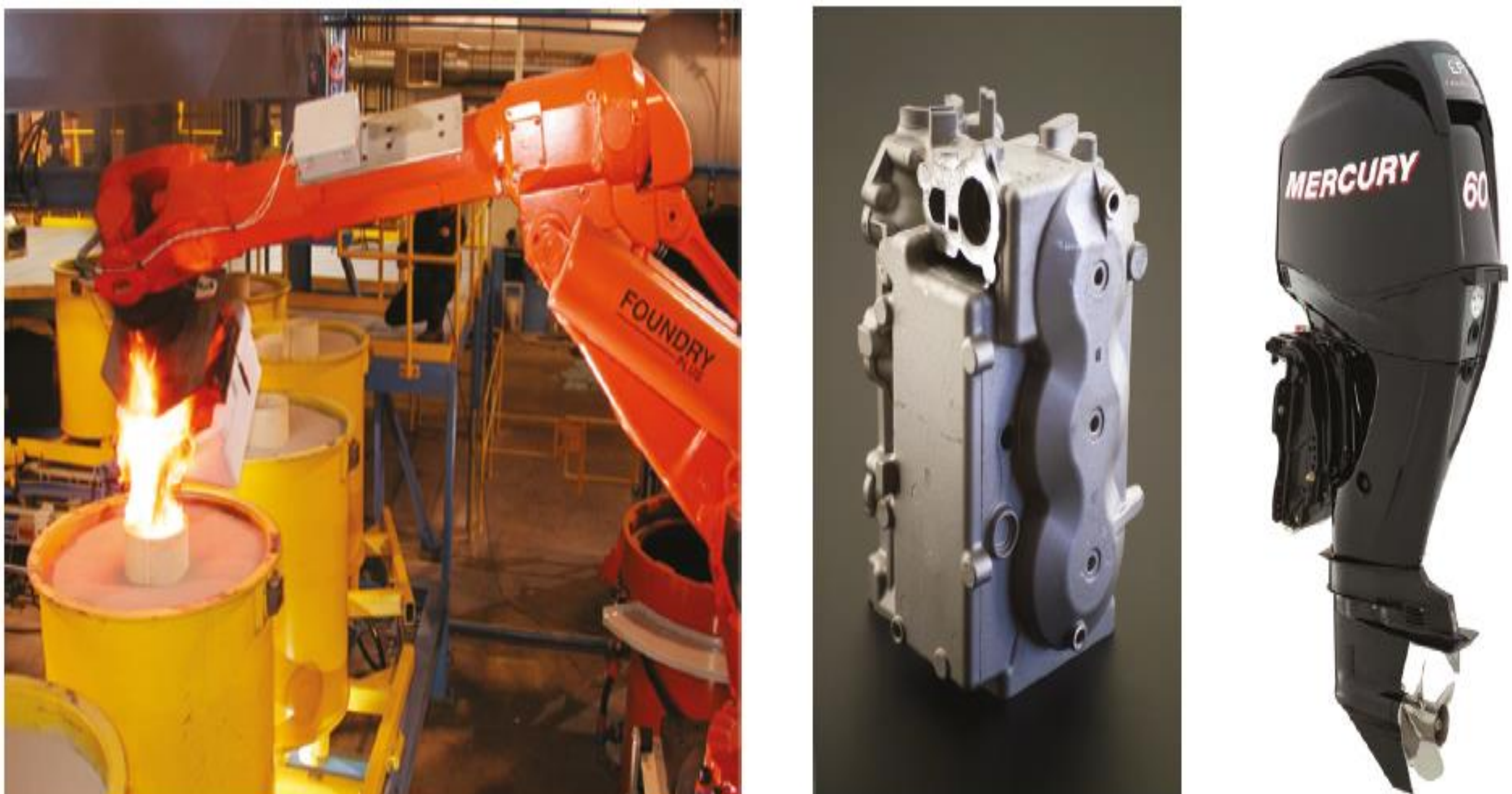
EVAPORATIVE PATTERN (FULL-MOLD AND LOST-FOAM) CASTING



Lost-foam Casting of Engine Blocks



Lost-foam Casting of Engine Blocks



(a) (b) (c)

Summary

Investment Casting

1. ***Process:*** A refractory slurry is formed around a wax or plastic pattern and allowed to harden. The pattern is then melted out and the mold is baked. Molten metal is poured into the mold and solidifies. The mold is then broken away from the casting

Lost Foam Casting

1. **Process:** A pattern containing a sprue, runners, and risers is made from single or multiple pieces of foamed plastic, such as polystyrene. It is dipped in a ceramic material, dried, and positioned in a flask, where it is surrounded by loose sand. Molten metal is poured directly onto the pattern, which vaporizes and is vented through the sand

Summary

Investment Casting

2. ***Advantages:*** Excellent surface finish; high dimensional accuracy; almost unlimited intricacy; almost any metal can be cast; no flash or parting line concerns.
3. ***Limitations***: Costly patterns and molds; labor costs can be high; limited size.

Lost FoamCasting

2. **Advantages:** Almost no limits on shape and size; most metals can be cast ;no draft is required and no flash is present (no parting lines).
3. **Limitations:** Pattern cost can be high for small quantities; patterns are easily damaged or distorted because of their low strength.

Summary

Investment Casting

4. ***Common metals**: Just about any castable metal. Aluminum, copper, and steel dominate; also performed with stainless steel, nickel, magnesium, and the precious metals.*
5. ***Size limits:** As small as 3 g (oz) but usually less than 5 kg (10 lb).*
6. ***Thickness limits**: As thin as 0.06 cm (0.025 in.), but less than 7.5 cm (3.0 in.).*

Lost Foam Casting

4. **Common metals:** Aluminum, iron, steel ,and nickel alloys ;also performed with copper and stainless steel.
5. **Size limits**: 0.5 kg to several thousand kg (1 lb to several tons).
6. **Thickness limits:** As small as 2.5 mm (0.1 in.) with no upper limit.

Summary

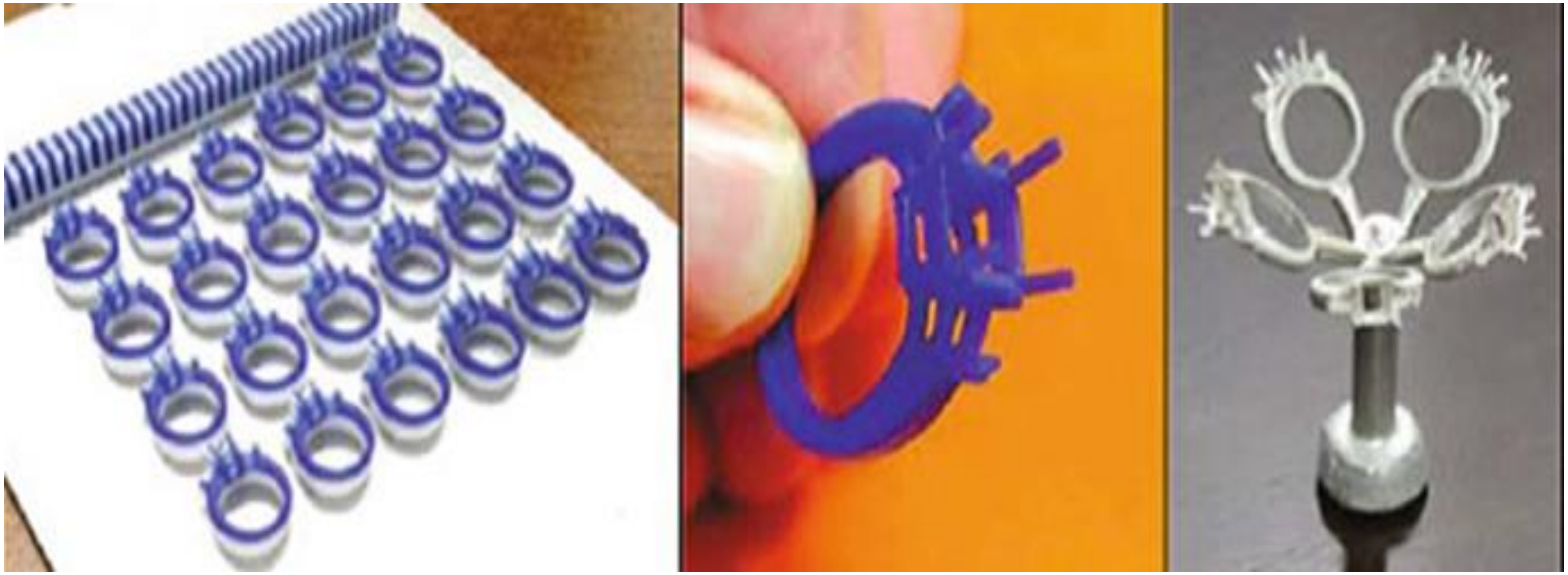
Investment Casting

7. ***Typical tolerances**:* 0.01 cm for the first 2.5 cm (0.005 in. for the first inch) and 0.002 cm for each additional cm (0.002 in. for each additional in.).
8. ***Draft allowances***: None required.
9. ***Surface finish:*** *1.3–4 microns (50 to 125 µin.) rms*

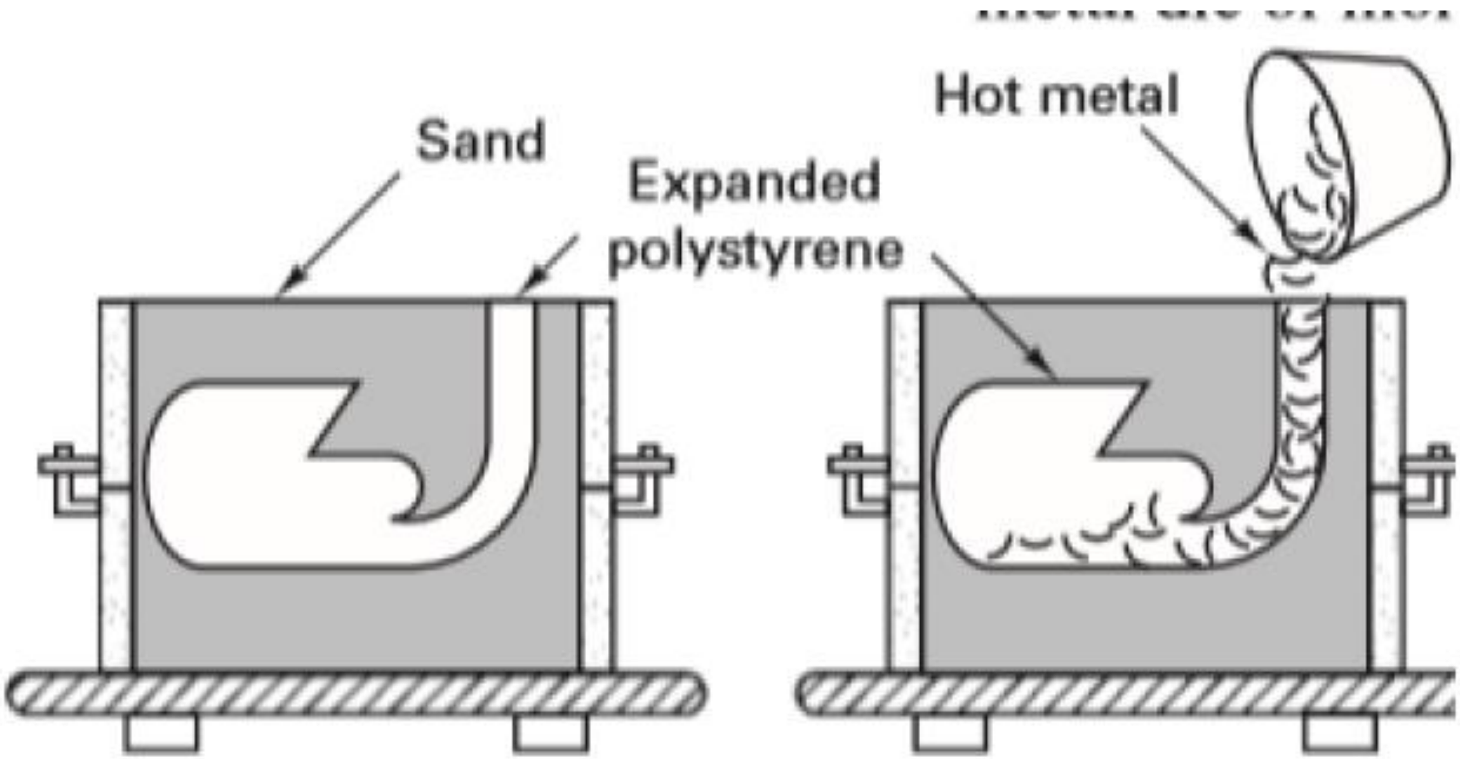
Lost Foam Casting

7. **Typical tolerances:** 0.003 cm/cm (0.003 in./in.) or less.
8. **Draft allowance:** None required.
9. **Surface finish**: 2.5–25 microns (100–1000 µin.) rms

Binder Jetting in *Investment Casting*



COUNTER-GRAVITY INVESTMENT CASTING



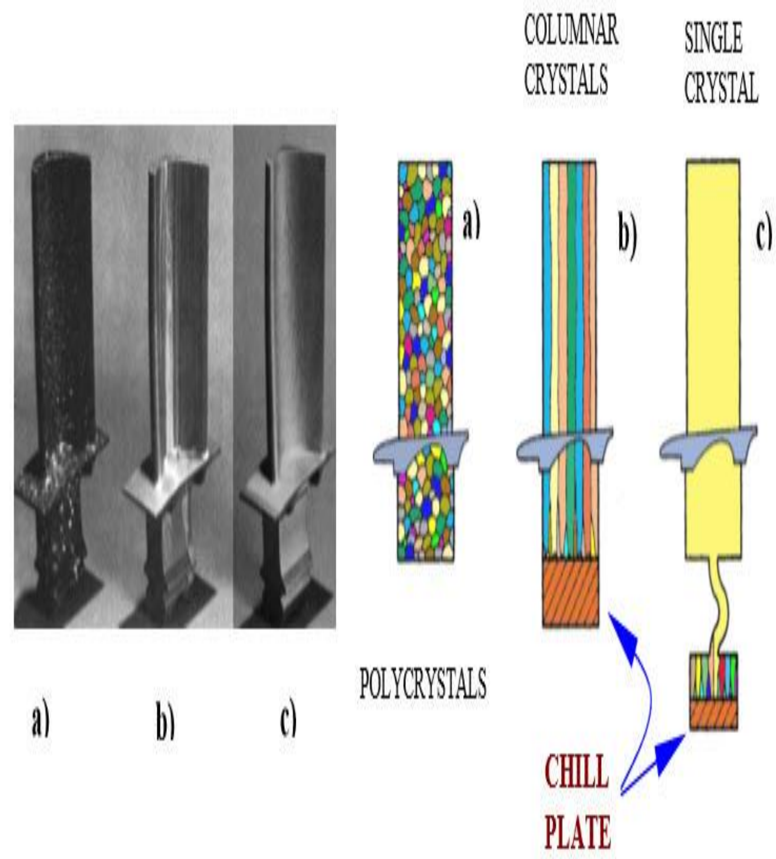
Advantages Of Counter-Gravity Investment Casting

1. Because the molten metal is withdrawn from below the surface of its ladle, it is generally free of slag and dross and has a very low level of inclusions.
2. The vacuum or low-pressure filling allows the metal to flow with little turbulence, further enhancing metal quality.
3. The reduction in metallic inclusions improves machinability and enables mechanical properties to approach or equal those of wrought material.
4. Since the gating system does not need to control turbulence, simpler gating systems can be used , reducing the amount of metal that does not become product.

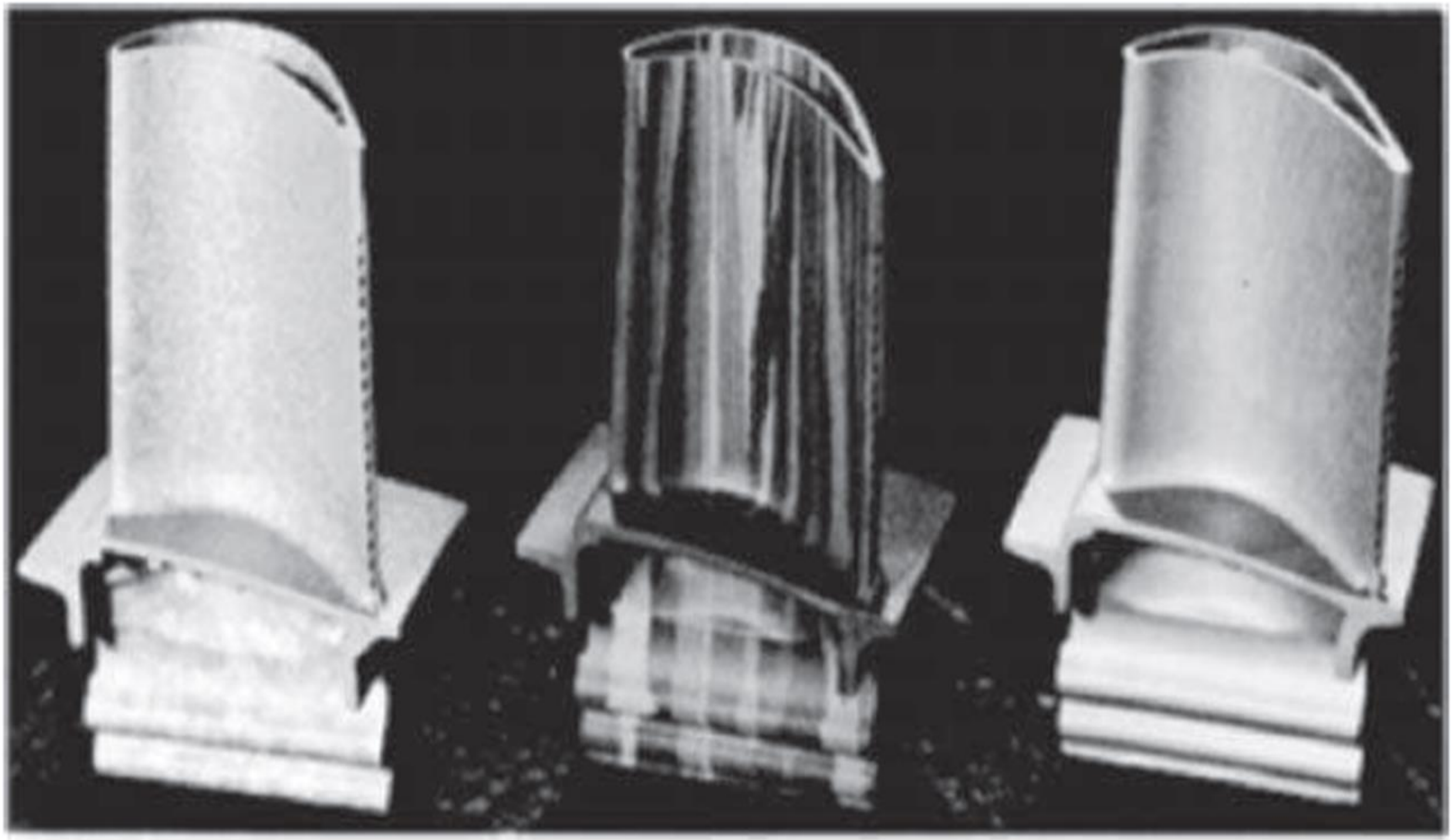
Investment Casting

Single Crystal casting

The advantage of single crystal growing techniques is well illustrated by describing the developments in casting of gas turbine blades, which are generally made of nickel-base super alloys. The procedures involved can also be used for other alloys and components

- 

Single-Crystal Blades



Equiaxed

Directional Solidified

Single Crystal

Single-Crystal Blades

The mold has a constriction in the shape of a corkscrew, the cross-section of which allows only one crystal through.

A single crystal grows upward through the constriction and begins to grow in the mold. Strict control of the rate of movement is necessary.

The solidified mass in the mold is a single-crystal blade. Although more expensive than other blades,

1. The Lack of grain boundaries makes these blades resistant to creep and thermal shock.

2. Thus they have a longer and more reliable service life .

Single Crystal casting

With the advent of the semiconductor industry, Single-crystal growing has become a major activity in the manufacture of microelectronic devices. There are several methods of crystal growing that are used world-wide,

1. Seed crystal growing (Crystal-pulling, Czochralski process)
2. Floating zone method
3. Hydrothermal synthesis (also termed: Hydrothermal growth/method

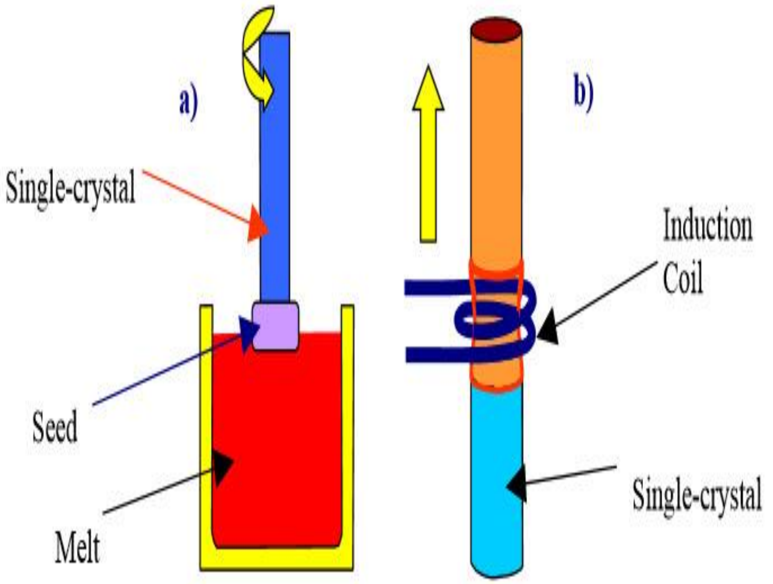
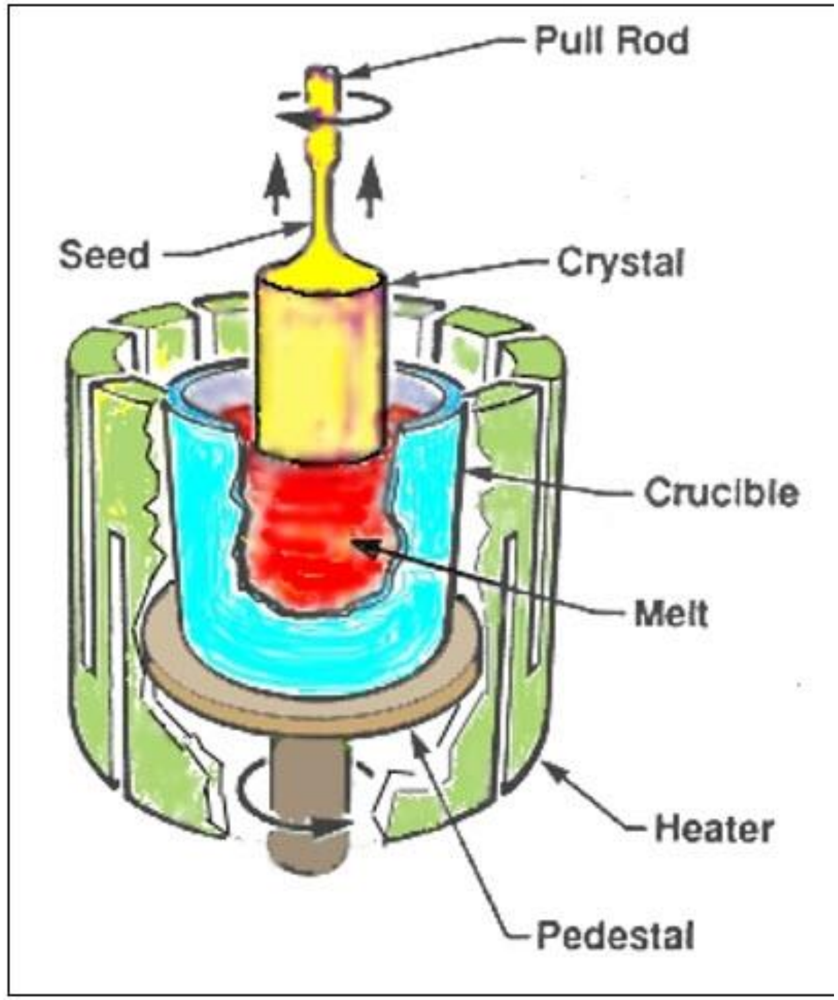


Fig 3.15: a) Crystal pulling and b) Floating-zone method

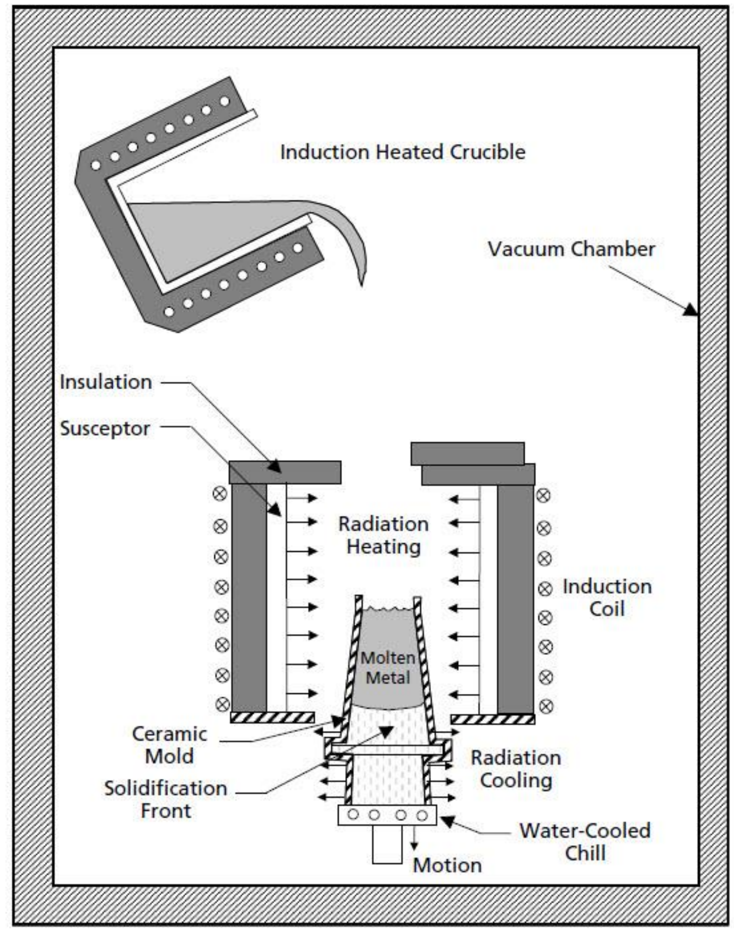
Single Crystal casting

Fig 3.16: Single Crystal Growth Apparatus



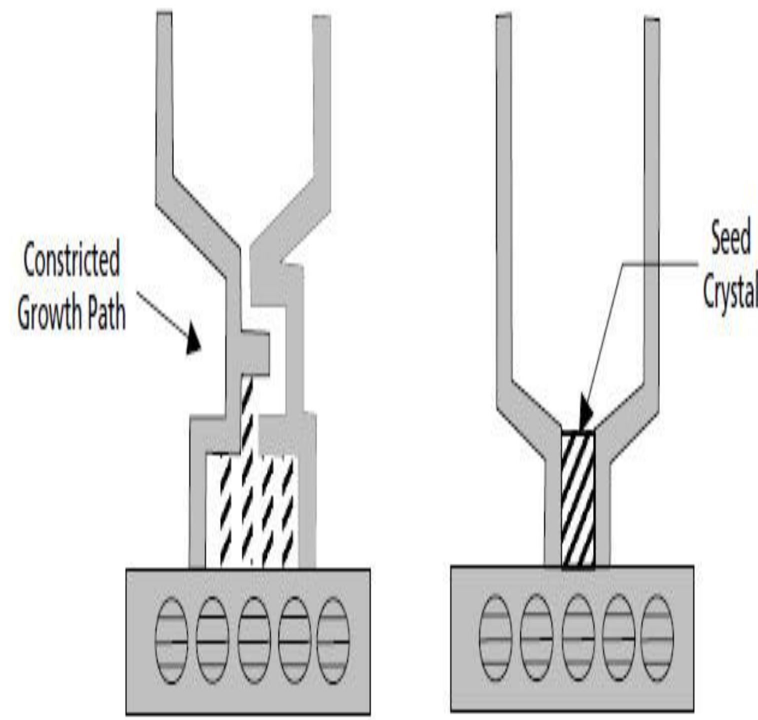
Directional Solidification (DS) Casting

- To develop a directionally solidified structure, it is necessary for the dendrites (grains) to grow from one end of the casting to the other.
- This is accomplished by creating a sharp temperature gradient, by removing the majority of the heat from one end of the casting. As shown in Fig. Aside, a water chilled mold is slowly withdrawn from the furnace, setting up a strong temperature gradient in the freezing metal.
- A thin wall investment casting mold, that is open at the bottom, is placed on a water-cooled copper chill plate



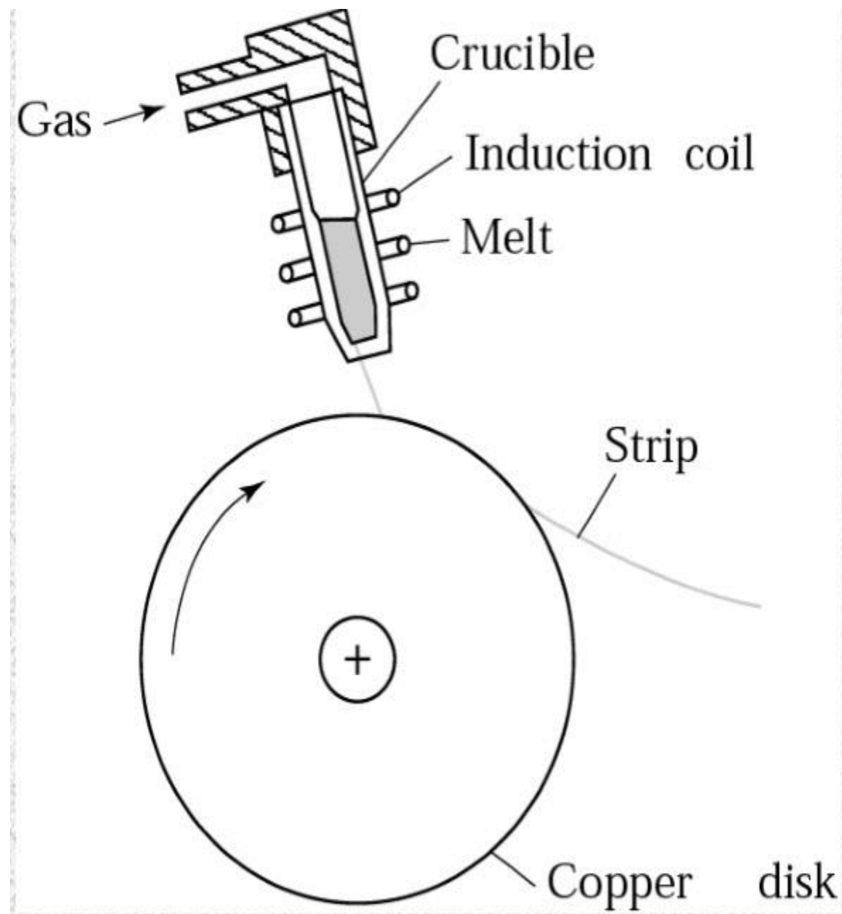
Single Crystal (SC) Casting

- Single crystal castings are produced in a manner similar to DS castings with one important difference; a method of selecting a single properly oriented grain is used.
- In the most prevalent method, a helical section of mold (Fig. Right) is placed between the chill plate and casting mold.
- This helix, or spiral grain selector, acts as a filter and allows only a single grain to pass through it



Rapid solidification

- involves cooling of a fluid at rates as high as 106 Kelvin/s, whereby the molten material does not have sufficient time to crystallize along the —long‖ distances. During rapid solidification crystals can grow at rates of up to 250 m/s however this fast growth in all directions reaches the level of the nucleation rates

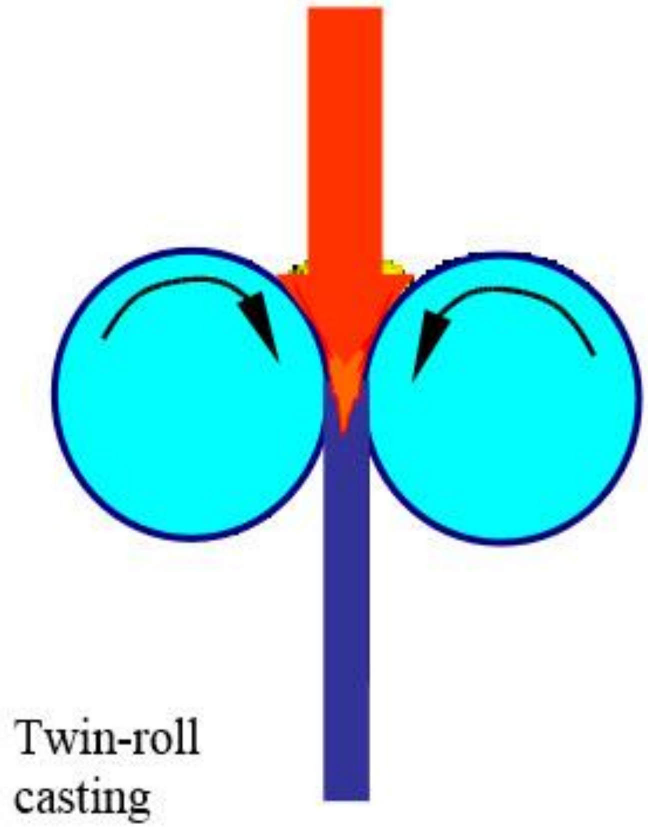


Amorphous Alloys (Metallic Glasses)

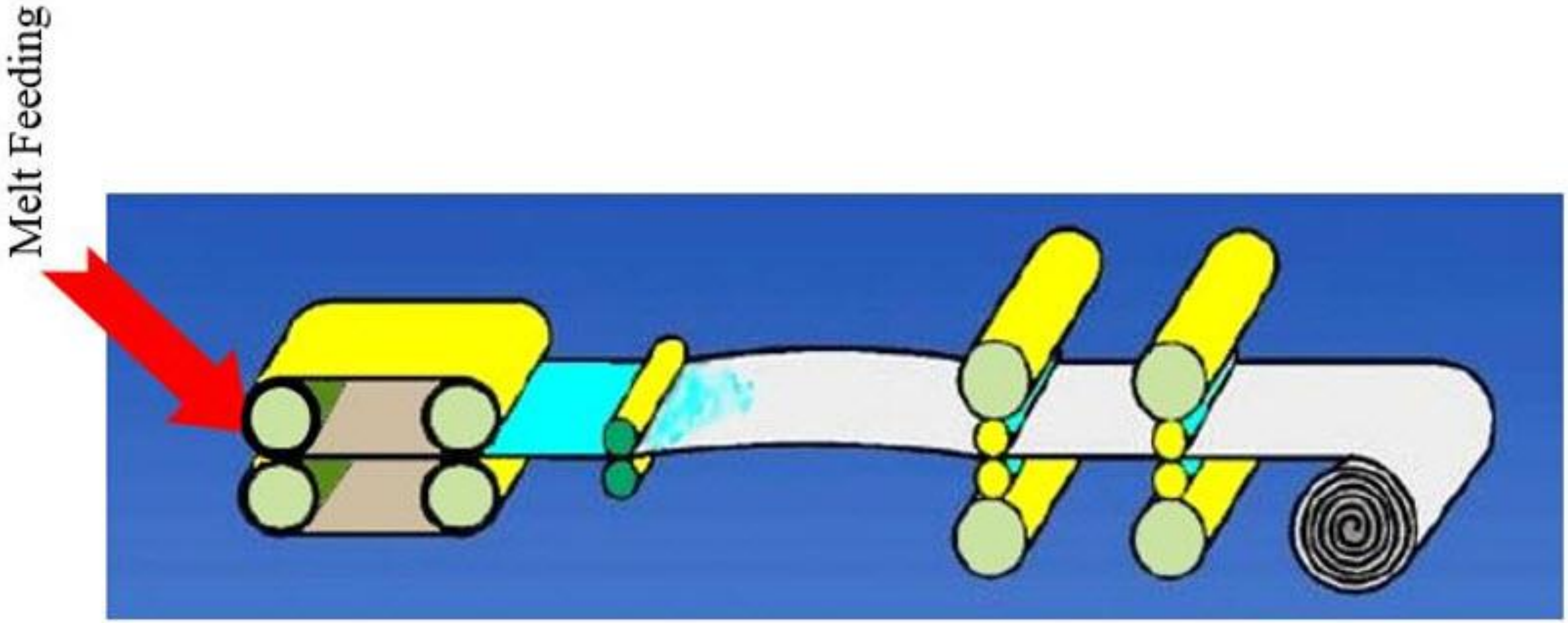
- class of metal alloys that, unlike metals, do not have a long-range crystalline structure is called amorphous alloys; these metals have no rain boundaries, and their atoms are packed randomly and tightly
- Amorphous alloys typically contain iron, nickel, and chromium, which are alloyed with carbon, phosphorus, boron, aluminum, and silicon.
- They are available as wire, ribbon, strip, and powder: One application is for faceplate inserts on golf-club heads; this alloy has a composition of zirconium, beryllium, copper, titanium, and nickel and is made by die casting.

Rapid solidification

A further method of rapid solidification is Twin Belt Caster Technique. Typical aspects of this production process include melt feeding, belt stabilization and control, heat transfer control, mould tapering, etc. Products include sheets, strips, tubes etc.



Rapid solidification



Twin Belt Casting

A further method of rapid solidification is Twin Belt Caster Technique. Typical aspects of this production process include melt feeding, belt stabilization and control, heat transfer control, mold tapering, etc. Products include sheets, strips, tubes etc.