Casting Processes

3.1 Sand Casting

Process Description

Moist bonding sand is packed around a pattern. The pattern is removed to create the mould and molten metal poured into the cavity. Risers supply necessary molten material during solidification. The mould is then broken to remove the part (Figure 3.1(a)).

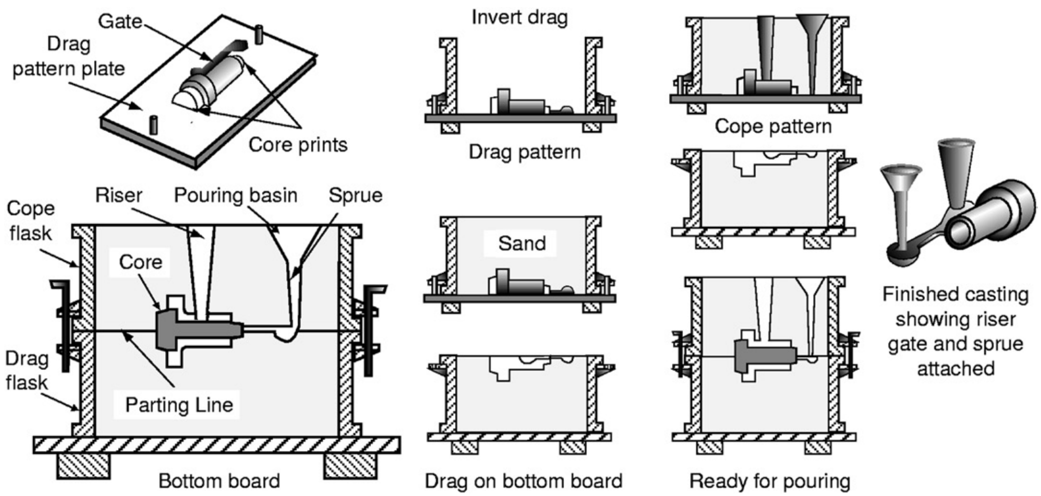

Figure 3.1(a): Sand Casting.

Materials

Most metals, particularly ferrous and aluminium alloys. Some difficulty encountered in casting: lead, tin and zinc alloys, also refractory alloys, beryllium, titanium and zirconia alloys.

Process Variations

- Green sand casting: the most common and the cheapest. Associated problems are that the mould has low strength and high moisture content.
- Dry sand: core boxes are used instead of patterns and an oven is used to cure the mould. Expensive and time consuming.

Manufacturing Process Selection Handbook. http://dx.doi.org/10.1016/B978-0-08-099360-7.00003-3

- Skin-dried sand: the mould is dried to a certain depth. Used in the casting of steels.
- Patterns: one-piece solid patterns are cheapest to make; split patterns for moderate quantities; match plate patterns for high-volume production.
- Wooden patterns: for low-volume production only.
- Metal patterns: for medium- to high-volume production. Hard plastics are also being used increasingly.
- Cosworth casting: low-pressure filling of mould used for better integrity, accuracy and porosity of casting. Longer production times and higher tooling costs, however.

Economic Considerations

- Production rates of 1–50/h, but dependent on size.
- Lead time typically days, but depends on complexity and size of casting.
- Material utilisation is low to moderate; 20–50% of material lost in runners and risers.
- Both mould material and runners and risers may be recycled.
- Patterns are easy to make and set, and are reusable.
- Pattern material dependent on the number of castings required.
- Easy to change design during production.
- Economical for low production runs of less than 100. Can be used for one-offs and high production volumes depending on degree of automation.
- Tooling costs are low.
- Equipment costs are low.
- Direct labour costs are high. Can be labour intensive.
- Finishing costs can be high. Cleaning and fettling required to remove gates and risers before secondary processing. Parting lines may also need finishing by hand.

Typical Applications

- Engine blocks.
- Manifolds.
- Machine tool bases.
- Pump housings.
- Cylinder heads.

Design Aspects

- High degree of shape complexity possible. Limited only by the pattern.
- Loose piece patterns can be used for holes and protrusions.
- All intersecting surfaces must be filleted: prevents shrinkage cracks and eliminates stress concentrations.

- Design of gating system for delivery of molten metal into mould cavity important.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Bosses, undercuts and inserts are possible, but at added cost.
- Steel inserts can be used as heat flow barriers.
- Cored holes greater than 6 mm diameter.
- Machining allowances are usually in the range 1.5–6 mm.
- Draft angle ranges from 1° to 5°.
- Minimum section typically 3 mm for light alloys, 6 mm for ferrous alloys.
- Sizes range from 25 g to 400 t in weight.

Quality Issues

- Moulding sand must be carefully conditioned and controlled.
- Most casting defects can be traced to and rectified by sand content.
- Casting shrinkage and distortion during cooling governed by shape, especially when one dimension is much larger than the other two.
- Extensive flat surfaces are prone to sand expansion defects.
- Inspection of castings is important.
- High porosity and inclusion levels are common in castings.
- Defects in castings may be filled with weld material.
- Castings generally have rough grainy surfaces.
- Material strength is inherently poor.
- Castings have good bearing and damping properties.
- If production volumes warrant the cost of a die, close tolerances may be achieved.
- Surface detail is fair.
- Surface roughness is a function of the materials used in making the mould and is in the range 3.2–50 μm Ra.
- Not suitable for close specification of tolerances without secondary processing.
- Process capability charts showing the achievable dimensional tolerances using various materials are provided (Figure 3.1(b)). Allowances of ±0.5 to ±2 mm should be added for dimensions across the parting line.

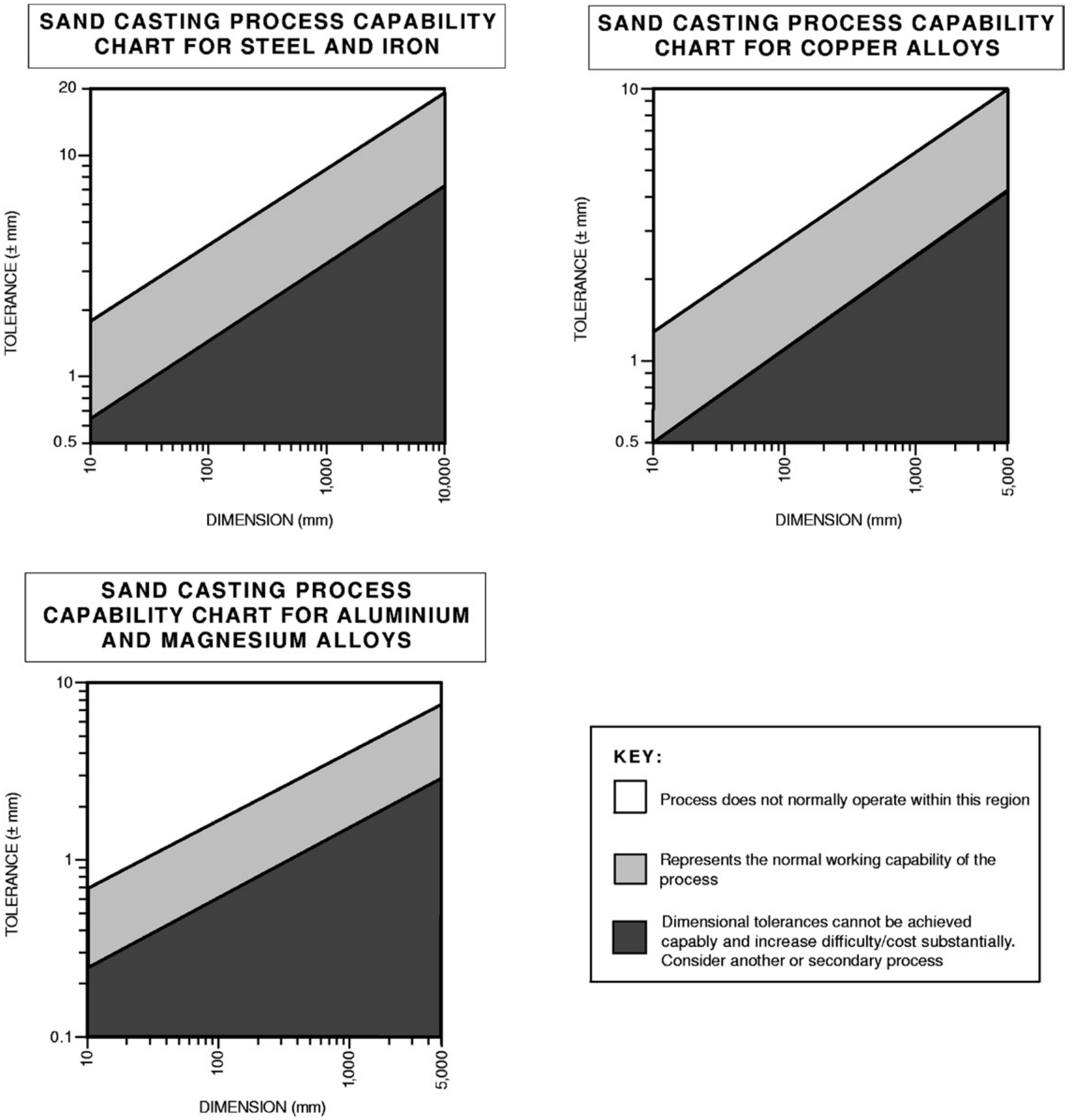

Figure 3.1(b): Sand Casting Process Capability Charts.

3.2 Shell Moulding

Process Description

A heated metal pattern is placed over a box of thermosetting resin-coated sand. The box is inverted for a fixed time to cure the sand. The box is re-inverted and the excess sand falls out. The shell is then removed from the pattern and joined with the other half (previously made). They are supported in a flask by an inert material ready for casting (Figure 3.2(a)).

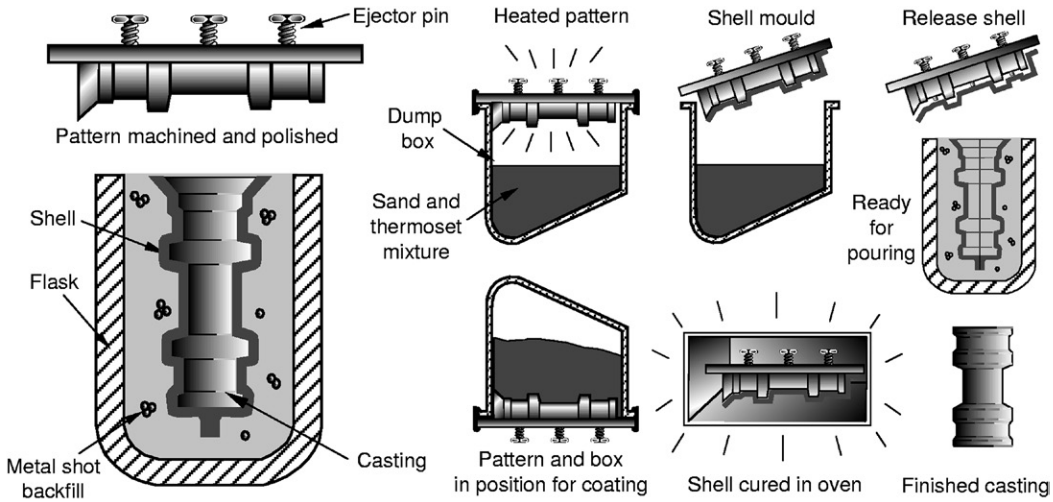

Figure 3.2(a): Shell Moulding.

Materials

Most metals, except: lead, zinc, magnesium and titanium alloys, also beryllium, refractory and zirconia alloys.

Process Variations

- Moulds produced from other casting processes may be joined with shell moulds.
- Patterns are generally made of iron or steel, giving good dimensional accuracy.
- Aluminium patterns may be used for low-volume production.
- Other pattern materials used are plaster, and graphite for reactive materials.

Economic Considerations

- Production rates of 5–200/h, but dependent on size.
- Lead time varies from several days to weeks depending on complexity and size.

- Material utilisation is high; little scrap generated.
- Potential for automation high.
- With use of gating systems several castings in a single mould are possible.
- Resin binders cost more, but only 5% as much sand is used as compared to sand casting.
- Difficult to change design during production.
- More suited to moderate- to high-volume production, but production volumes of 100–500 may be economical.
- Considered best of low-cost casting methods for large quantities.
- Tooling costs are low to moderate.
- Equipment costs are moderate to high.
- Labour costs are low to moderate.
- Low finishing costs. Often no finishing required.

Typical Applications

- Small mechanical parts requiring high precision.
- Gear housings.
- Cylinder heads.
- Connecting rods.
- Transmission components.

Design Aspects

- Good for moulding complex shapes, especially when using composite moulds.
- Great variations in cross-section possible.
- Sharper corners, thinner sections, smaller projections than possible with sand casting.
- Bosses and inserts possible.
- Undercuts difficult.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Cored holes greater than 3 mm diameter.
- Draft angle ranges from 0.25° to 1°, depending on section depth.
- Maximum section = 50 mm.
- Minimum section = 1.5 mm.
- Sizes range from 10 g to 100 kg in weight. Better for small parts less than 20 kg.

Quality Issues

- Blowing sand on to pattern makes deposition more uniform, especially good for intricate forms.
- Few castings are scrapped due to blowholes or pockets. Gases are able to escape through thin shells or venting.

- Composite cores may include chills and cores to control solidification rate in critical areas.
- Moderate porosity and inclusions.
- Mechanical properties are better than sand casting.
- Uniform grain structure.
- Surface detail good.
- Surface roughness is in the range 0.8–12.5 μm Ra.
- Process capability charts showing the achievable dimensional tolerances using various materials are provided (Figure 3.2(b)). Allowances of ±0.25 to ±0.5 mm should be added for dimensions across the parting line.

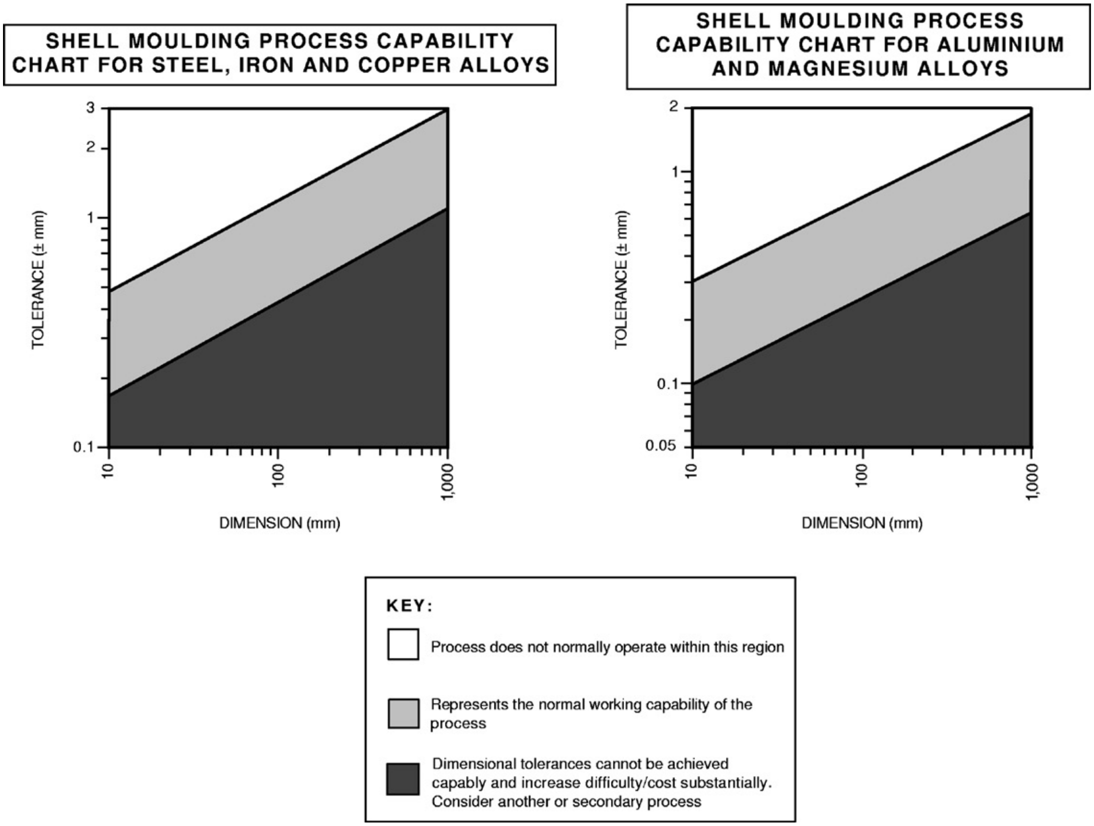

Figure 3.2(b): Shell Moulding Process Capability Charts.

3.3 Gravity Die Casting

Process Description

Molten metal is poured under gravity into a pre-heated die, where it solidifies. The die is then opened and the casting ejected. Also known as permanent mould casting (Figure 3.3(a)).

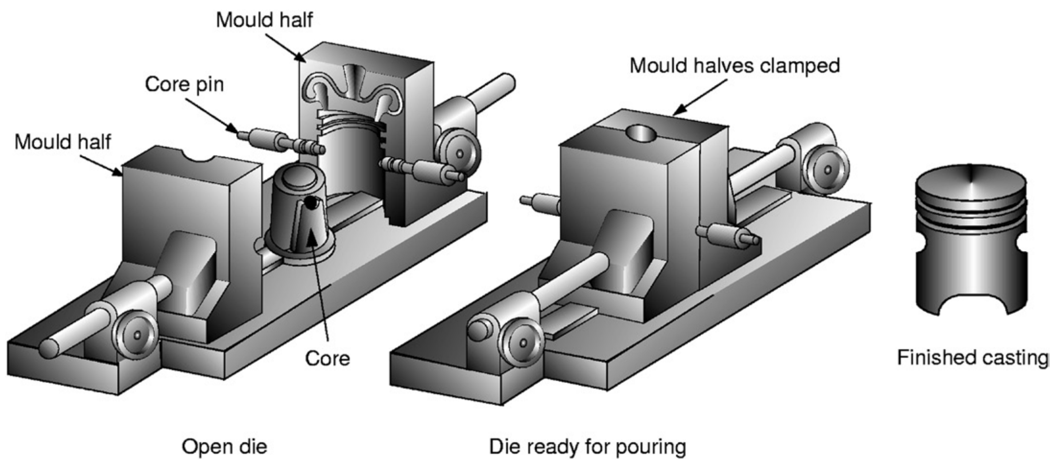

Figure 3.3(a): Gravity Die-Casting.

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.

Process Variations

- Dies typically cast iron, graphite or refractory material.
- Metal or sand cores can be used although surface finish can be poor.
- Low pressure die-casting: uses low-pressure (1 bar) air to force the molten metal into the die cavity. Less popular than gravity die-casting, and tends to be used purely for the production of car wheels. Gives lower production rates.
- Slush casting: for creating hollow parts without cores in low-melting-point metals such as lead, zinc and copper alloys.

Economic Considerations

- Production rates of 5–50/h, but dependent on size.
- Lead times can be many weeks.
- Material utilisation is moderate to high (10–40% lost in scrap, but can be recycled).

- If accuracy and surface finish is not an issue, can use sand cores instead of metallic or graphite for greater economy.
- Production volumes of 500–1,000 may be viable, but suited to higher volume production.
- Tooling costs are moderate.
- Equipment costs are moderate.
- Labour costs are low to moderate.
- Finishing costs are low to moderate. Gates need to be removed.

Typical Applications

- Cylinder heads.
- Engine connecting rods.
- Pistons.
- Gear and die blanks.
- Kitchen utensils.
- Gear blanks.
- Gear housings.
- Pipe fittings.
- Wheels.

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 are usually in the range 0.8–1.5 mm.
- Vertical parting lines commonly used.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Cored holes greater than 5 mm diameter.
- Draft angle ranges from 2° to 3°.
- Maximum section = 50 mm.
- Minimum section = 2 mm.
- Sizes range from 50 g to 300 kg in weight. Commonly used for castings less than 5 kg.

Quality Issues

- Little porosity and inclusions. Can be minimised by slow die filling to reduce turbulence.
- 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.
- Surface detail good.
- Surface roughness is in the range 0.8–6.3 μm Ra.
- Process capability charts showing the achievable dimensional tolerances using various materials are provided (Figure 3.3(b)). Allowances of ±0.25 to ±0.75 mm should be added for dimensions across the parting line.

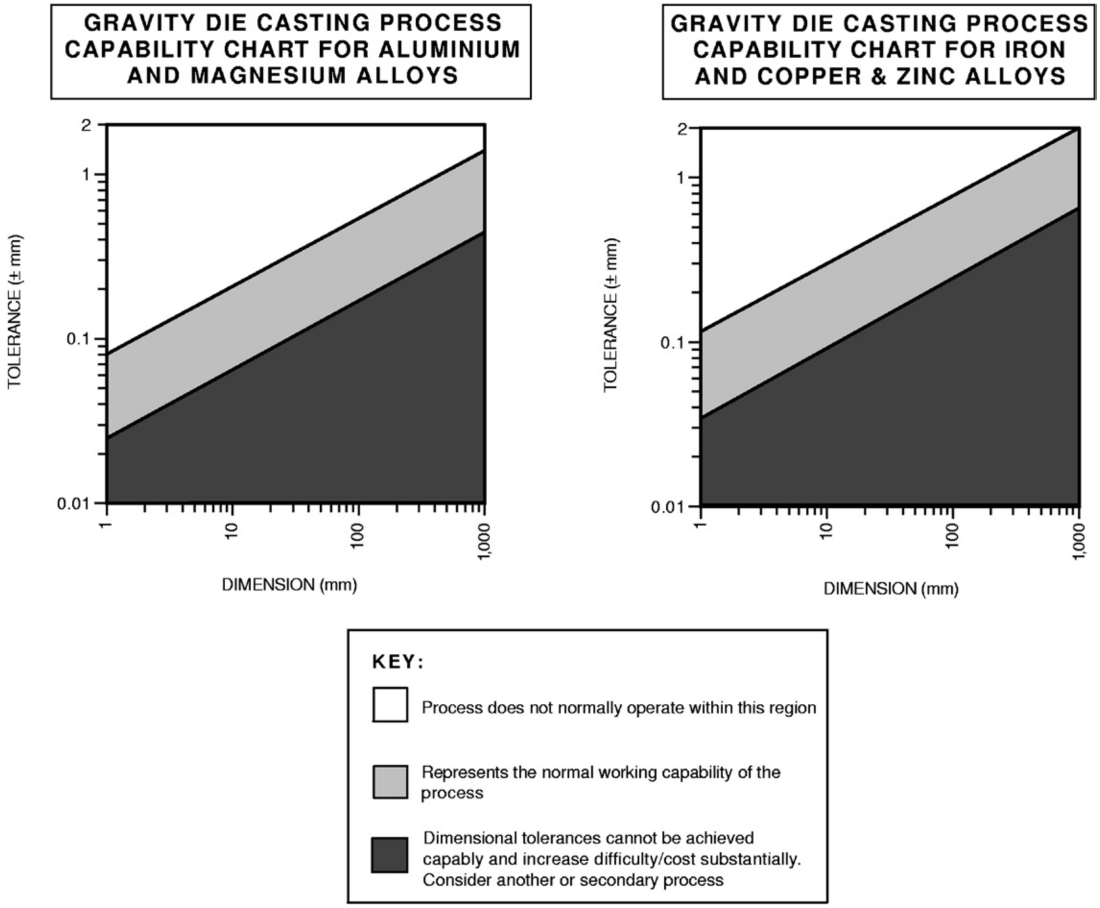

Figure 3.3(b): Gravity Die Casting Process Capability Charts.

3.4 Pressure Die Casting

Process Description

Molten metal is inserted into a metallic mould under very high pressures (100+ bar), where it solidifies. The die is then opened and the casting ejected (Figure 3.4(a)).

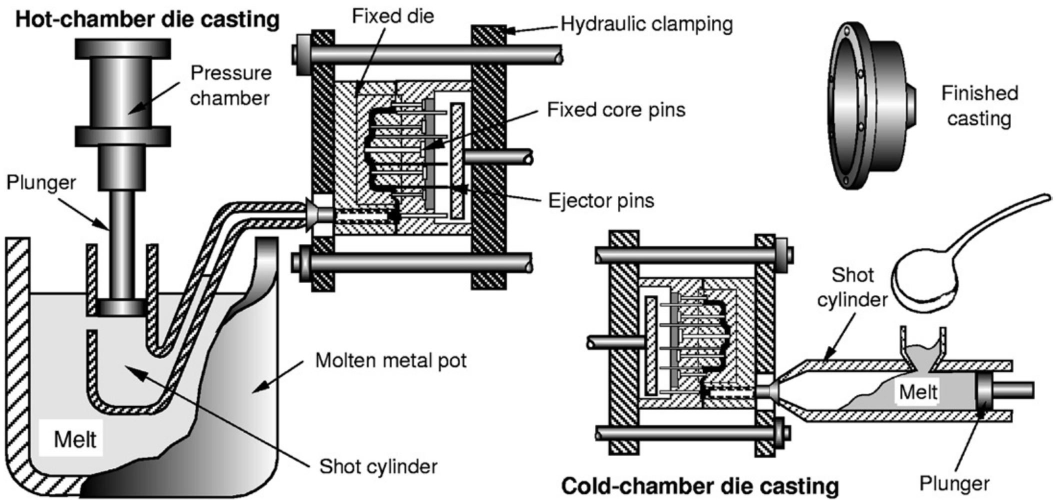

Figure 3.4(a): Pressure Die Casting.

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 materials.
- High-temperature metals, such as copper alloys, reduce die life.
- Iron-based materials for casting are under development.

Process Variations

- Dies and cores are made from hardened and tempered alloy steel.
- Cold-chamber die casting: shot cylinder filled with a ladle for each cycle. Used for high melting temperature metals.
- Hot-chamber die casting: shot cylinder immersed in molten metal and then forced using a separate ram. Used for low melting temperature metals due to erosive nature of molten metal. Can be either plunger or goose-neck type.
- Vacuum die casting: overcomes porosity for larger castings.

- Injection metal assembly: variant of hot chamber die casting for the assembly of parts such as tubes and plates, cable terminations and to act as rivets by injecting zinc or lead alloys into a cavity in the assembly.

Economic Considerations

- Very high production rates possible, up to 200/h.
- Lead time very long, months possibly.
- Material utilisation is high.
- Gates, sprues, etc. can be re-melted.
- High initial die costs due to high complexity and difficulty to manufacture.
- Full automation achievable. Robot machine loading and unloading common.
- Production quantities of up to 10,000 are economically viable for copper alloys, but 100,000+ for aluminium, zinc and lead alloys.
- Tooling costs are very high.
- Equipment costs are very high.
- Direct labour costs are low.
- Finishing costs are low. Trimming operations are required to remove flash, gates and sprues.

Typical Applications

- Transmission cases.
- Machine and engine parts.
- Pump components.
- Electrical boxes.
- Domestic appliance components.
- Toy bodies.
- Pump and impeller parts.

Design Aspects

- Shape complexity can be high. Limited by design of movable cores.
- Bosses, large threads, undercuts and inserts are all possible with added cost.
- Moulded-in bearing shells possible.
- Lettering possible.
- Wall thickness should be as uniform as possible; transitions should be gradual.
- Sharp corners should be avoided, but pressure die casting permits smaller radii because metal flow is aided.
- Placing of parting line important, i.e. avoid placement across critical dimensions.

- Holes perpendicular to the parting line can be cast.
- Casting holes for subsequent tapping is generally more economical than drilling.
- Cored holes greater than 0.8 mm diameter.
- Machining allowance is normally in the range 0.25–0.8 mm.
- Draft angle ranges from 0.25° to 3°, depending on section depth.
- Maximum section = 13 mm.
- Minimum section ranges from 0.4 mm for zinc alloys to 1.5 mm for copper alloys.
- 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.

Quality Issues

- Low porosity in small castings typically, but can be a problem in castings with thick or long sections.
- 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.
- Ejector pins may leave small marks and should be positioned at points of strength on the casting.
- Process variables need to be controlled. Variation in temperature, pressure and cycle time especially important for consistency.
- 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 fair, but poorer than some other casting methods.
- Surface detail excellent.
- Surface roughness is in the range 0.4–3.2 μm Ra.
- Process capability charts showing the achievable dimensional tolerances using various materials are provided (Figure 3.4(b)). Allowances of ±0.05 to ±0.35 mm should be added for dimensions across the parting line.

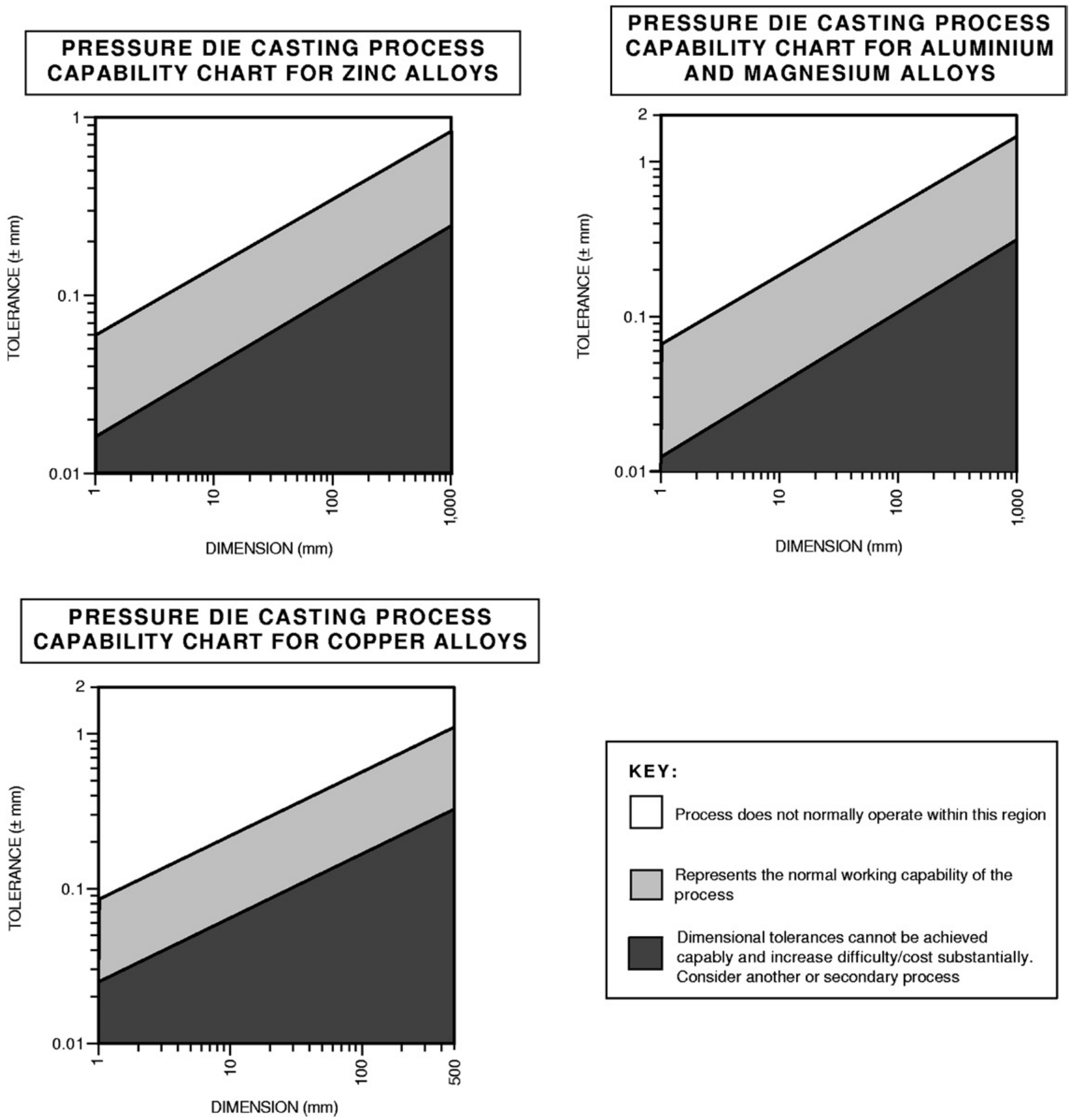

Figure 3.4(b): Pressure Die Casting Process Capability Charts.

3.5 Centrifugal Casting

Process Description

Molten metal is poured into a high-speed rotating mould (300–3000 rpm depending on diameter) until solidification takes place. The axis of rotation is usually horizontal, but may be vertical for short work pieces (Figure 3.5(a)).

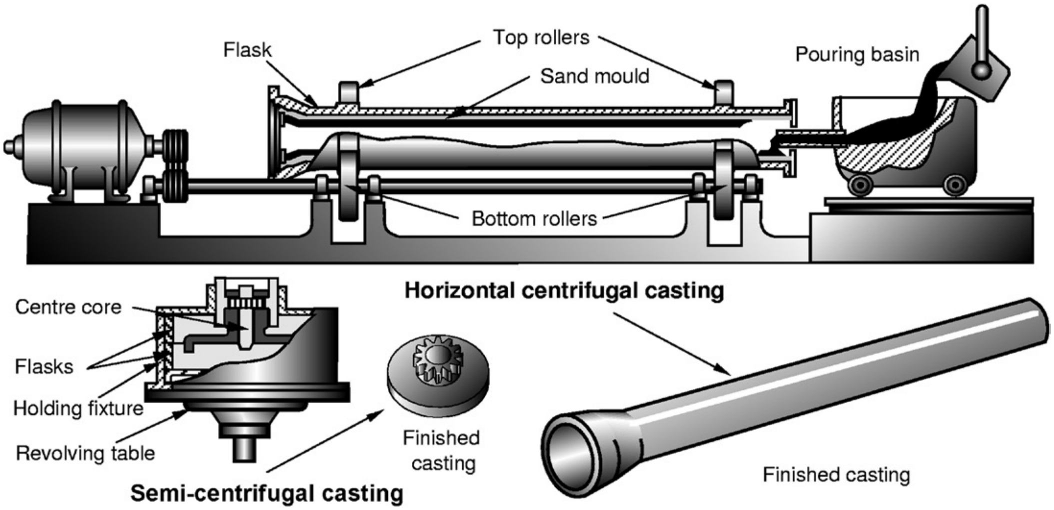

Figure 3.5(a): Centrifugal Casting.

Materials

- Most metals suitable for static casting are suitable for centrifugal casting: all steels, iron, copper, aluminium and nickel alloys.
- Also, glass, thermoplastics, composites and ceramics (metal moulds sprayed with a refractory material) can be moulded by this method.

Process Variations

- Semi-permanent or expendable moulds.
- Semi-centrifugal casting: used to cast parts with radial symmetry in a vertical axis of rotation at low speeds.
- Centrifuge casting: a number of moulds are arranged radially around a central sprue. Molten metal is poured into the sprue and is forced into the mould cavities by centrifugal force due to high-speed rotation. Used for small gears mainly and parts of intricate detail.

Economic Considerations

- Production rates of up to 50/h possible, but dependent on size.
- Lead time may be several weeks.
- Material utilisation high (90–100%). No runners or risers.
- Economic when the mechanical properties of thick-walled tubes are important and high alloy grades of steel are required.
- In large quantities production of other than circular external shapes becomes more economical.
- Small-diameter steel tubes made by this method are not competitive with welded or rolled tubes.
- Selection of mould type (permanent or sand) is determined by shape of casting, quality and number to be produced.
- Production volumes are low, typically 100+. Can be used for one-offs.
- Tooling costs are moderate.
- Equipment costs are low to moderate.
- Direct labour costs are low to moderate.
- Finishing costs are low to moderate. Normally, machining of internal dimension necessary.

Typical Applications

- Pipes.
- Brake drums.
- Pulley wheels.
- Train wheels.
- Flywheels.
- Gun barrels.
- Gear blanks.
- Large bearing liners.
- Engine-cylinder liners.
- Pressure vessels.
- Nozzles.

Design Aspects

- Shape complexity limited by nature of process, i.e. suited to parts with rotational symmetry.
- Contoured surfaces possible.
- Circular bore remains in the finished part.

- Dual metal tubes that combine the properties of two metals in one application are possible.
- Inserts and bosses are possible, but undercuts are not.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Cored holes greater than 25 mm diameter.
- Machining allowances range from 0.75 to 6 mm.
- Draft angle approximately 1°.
- Maximum section thickness approximately 125 mm.
- Minimum section ranges from 2.5 to 8 mm, depending on material cast.
- Maximum length = 15 m.
- Sizes range from 25 mm to 2 m diameter.
- Sizes up to 5 t in weight have been cast.

Quality Issues

- Properties of castings vary by distance from the axis of rotation.
- Due to density differences in the molten material, dross, impurities and pieces of the refractory lining tend to collect on the inner surface of the casting. This is usually machined away.
- Tubular castings have higher structural strengths and more distinct cast impressions than gravity die cast or sand cast parts.
- Castings are free of shrinkage due to one-directional cooling.
- The mechanical properties of dense castings are comparable with that of forgings. Fine-grain castings and low porosity are an advantage.
- Good mechanical properties and fine grain structure.
- Surface detail fair to good.
- Surface roughness is in the range 1.6–12.5 μm Ra.
- A process capability chart showing the achievable dimensional tolerances is provided (Figure 3.5(b)). Allowances of approximately ±0.25 to ±0.75 mm should be added for dimensions across the parting line. Note, the chart applies to outside dimensions only. Internal dimensions are approximately 50% greater.

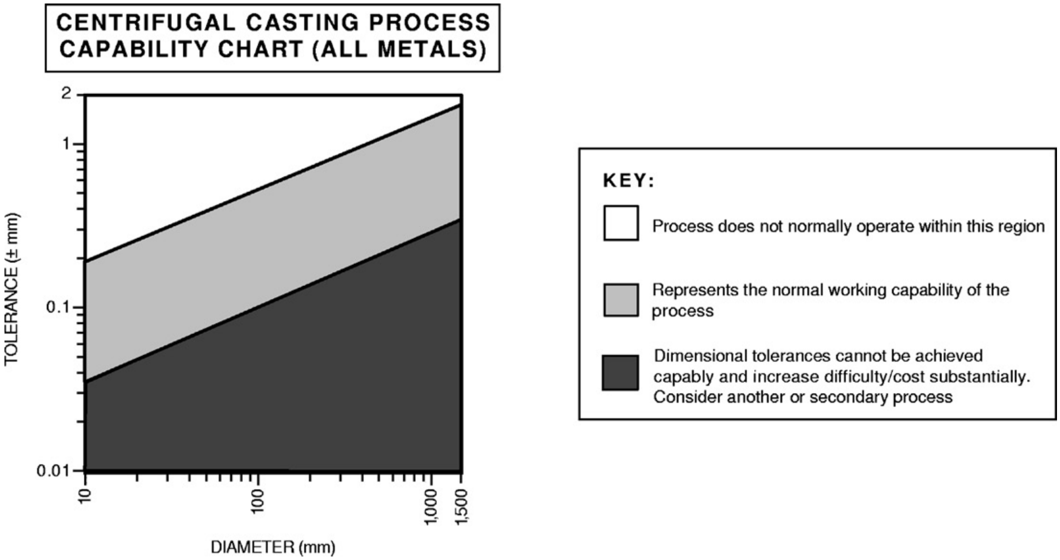

Figure 3.5(b): Centrifugal Casting Process Capability Chart.

3.6 Investment Casting

Process Description

A mould is used to generate a wax pattern of the shape required. A refractory material zircon, then a ceramic slurry and finally a binder is used to coat the pattern, which is slow fired in an oven to cure. The wax is melted out and the metal cast in the ceramic mould. The mould is then destroyed to remove the casting. Process often known as the 'lost wax' process (Figure 3.6(a)).

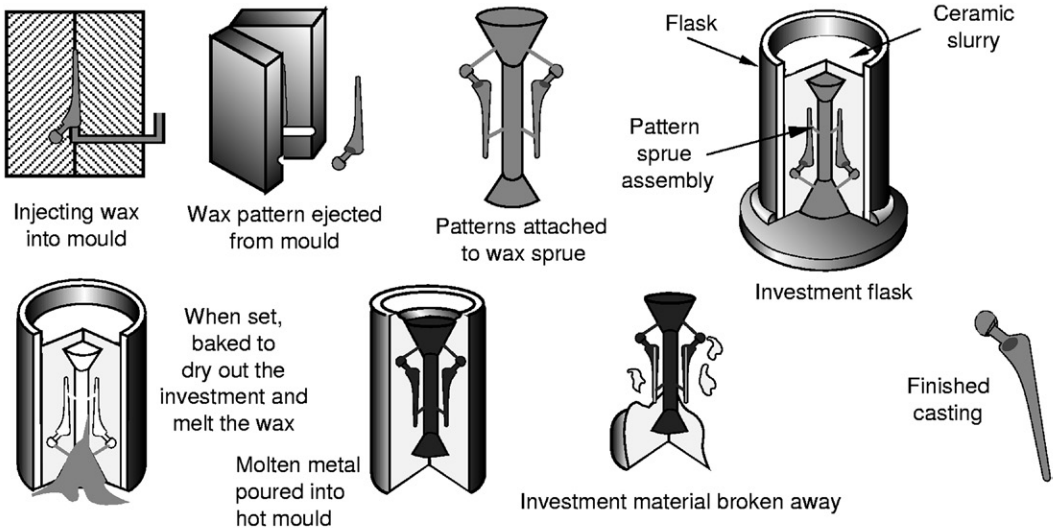

Figure 3.6(a): Investment Casting.

Materials

All metals, including precious, refractory and reactive alloys (cast in vacuum).

Process Variations

- Blends of resin, filler and wax used.
- Use of thermoplastic resin instead of wax.
- Ceramic and water-soluble cores can be used.

Economic Considerations

- Production rates of up to 1,000/h, depending on size.
- Lead times are usually several weeks, but can be shorter.

- Slow process due to many steps in production. Cure time can be as high as 48 hours.
- Wax or plastic patterns can be injection-moulded for high production volumes.
- Best suited to metals having high melting temperatures, and/or which are difficult to machine or are costly.
- Material utilisation is high.
- Some automation possible.
- Pattern costs can be high for low quantities.
- Ceramic and wax cores allow complex internal configurations to be produced, but increase the cost significantly.
- A 'tree' of wax patterns enables many small castings to be handled together.
- Most suitable for small batches (10–1,000) using manual labour, but also high-volume production with automation.
- Sometimes used for one-offs, especially in decorative work.
- Tooling costs are low to moderate, but dependent on complexity.
- Equipment costs are low to moderate (high when processing reactive materials).
- Labour costs are very high. Can be labour intensive as many operations are involved.
- Low to moderate finishing costs. Gates and feeders are removed by machining or grinding. As cast part typically cleaned by shot, bead or sand blasting.

Typical Applications

- Turbine blades.
- Machine tool parts.
- Aerospace components.
- Valve and pump casings.
- Pipe fittings.
- Automotive engine components.
- Decorative work, e.g. figurines.
- Optical instrument parts.
- Small arms parts.
- Gear blanks.
- Levers.
- Jewellery.

Design Aspects

- Very complex castings with unusual internal configurations possible.
- Wax pattern must be easily removable from its mould.
- Complex shapes may be assembled from several simpler shapes.

- Practical way of producing threads in hard-machine materials, or where thread design is unusual.
- Uniform sections are preferred. Abrupt changes should be gradually blended in or designed out.
- Avoid sharp corners.
- Fillets should be as generous as possible.
- Bosses and undercuts are possible with added cost.
- Inserts are not possible, but integral rivets are.
- Lettering possible, either in relief or inset.
- Moulded-in holes, both blind and through, are possible but difficult.
- Length to diameter ratio for blind holes is typically 4:1.
- Minimum hole = 0.5 mm diameter.
- Machining allowance usually between 0.25 and 0.75 mm, depending on size.
- Draft angle usually zero, but 0.5–1° desirable on long extended surfaces, or if mould cavity is deep.
- Minimum section ranges from 1 mm for aluminium alloys and steels, 2 mm for copper alloys, but can be as low as 0.6 mm for some applications.
- Maximum section = 75 mm.
- Maximum dimension = 1 m.
- Sizes range from 0.5 g to 100 kg in weight, but best for parts less than 5 kg.

Quality Issues

- Moderate porosity.
- High-strength castings can be produced.
- Grain growth more pronounced in longer sections, which may limit the toughness and fatigue life of the part.
- Quality of casting depends to a large degree upon the characteristics of wax.
- Very good to excellent surface detail possible.
- Surface roughness is in the range 0.4–6.3 μm Ra.
- Flatness tolerances typically ±0.13 mm per 25 mm, but dependent on surface area.
- Minimum angular tolerance = ±0.5°.
- A process capability chart showing the achievable dimensional tolerances is provided (Figure 3.6(b)).
- No parting line on casting.

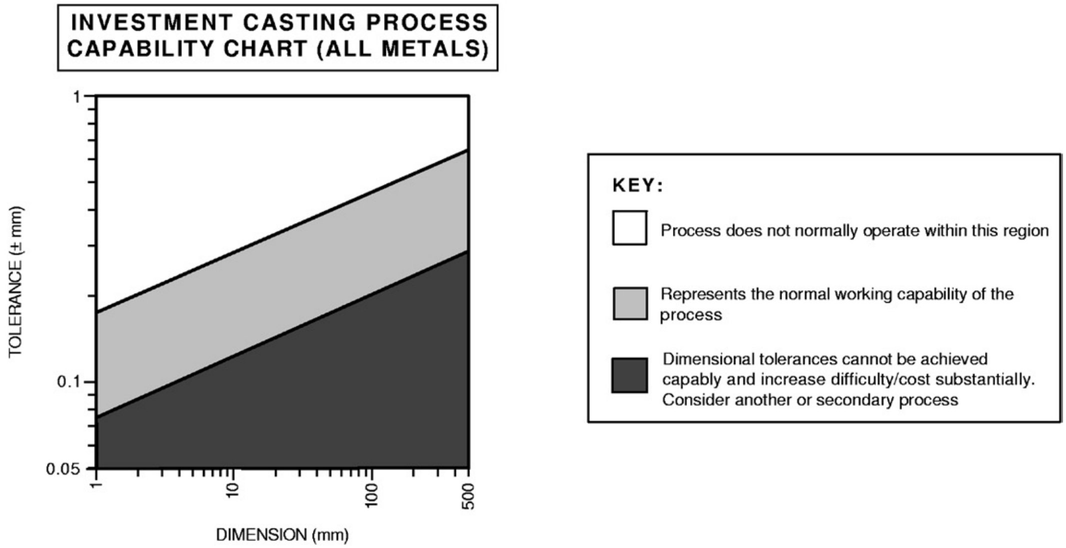

Figure 3.6(b): Investment Casting Process Capability Chart.

3.7 Ceramic Mould Casting

Process Description

A precision pattern generates the mould, which is coated with a ceramic slurry. The mould is dried and baked. The molten metal is then poured into the mould and allowed to solidify. The mould is broken to remove the part (Figure 3.7(a)).

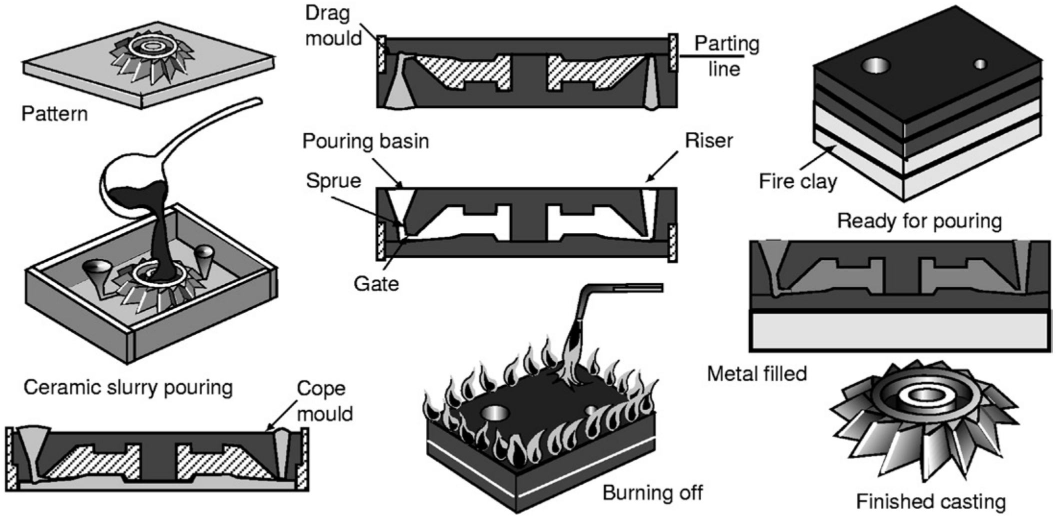

Figure 3.7(a): Ceramic Mould Casting.

Materials

All metals, but to a lesser degree aluminium, magnesium, zinc, tin and copper alloys.

Process Variations

- Variations on the composition of the ceramic slurry and curing mechanism.
- Plaster, wood, metal or rubber are used for patterns.

Economic Considerations

- Production rates of up to 10/h typical.
- Lead times can be several days.
- Material utilisation is high.
- Low scrap losses.

- Best suited to metals having high melting temperatures and/or that are difficult to machine.
- Can be combined with investment casting to produce parts with increased complexity with reduced cost.
- Suitable for small batches and medium-volume production.
- Can be used for one-offs.
- Tooling costs are moderate.
- Equipment costs are moderate to high.
- Direct labour costs are moderate to high.
- Finishing costs are low. Usually no machining is required.

Typical Applications

- All types of dies and moulds for other casting and forming processes.
- Cutting tool blanks.
- Components for food handling machining.
- Pump impellers.
- Aerospace and atomic reactor components.

Design Aspects

- High complexity possible – almost any shape possible.
- Use of cores increase complexity obtainable.
- Inserts, bosses and undercuts are possible.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Cored holes greater than 0.5 mm diameter.
- Where machining is required, allowances of up to 0.6 mm should be observed.
- Draft angle usually zero, but 0.1–1° preferred.
- Minimum section ranges from 0.6 to 1.2 mm, depending on material used.
- Sizes range from 100 g to 3 t in weight, but less than 50 kg better.

Quality Issues

- Low porosity.
- Mechanical properties are good.
- Good surface detail possible.
- Surface roughness is in the range 0.8–6.3 μm Ra.
- A process capability chart showing the achievable dimensional tolerances is provided (Figure 3.7(b)). An allowance of ±0.25 mm should be added for dimensions across the parting line.
- Parting lines are sometimes pronounced on finished casting.

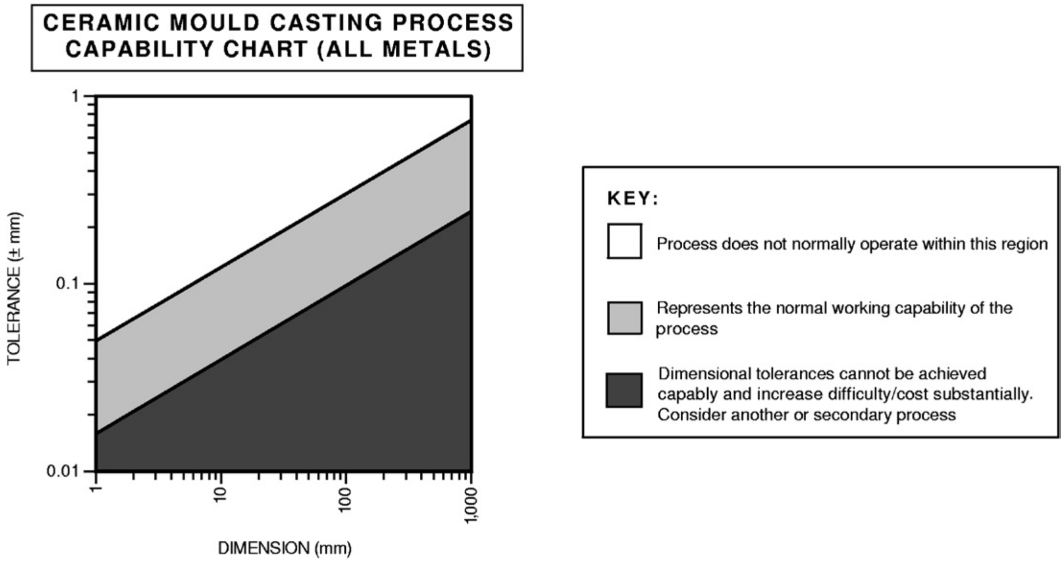

Figure 3.7(b): Ceramic Mould Casting Process Capability Chart.

3.8 Plaster Mould Casting

Process Description

A precision metal pattern (usually brass) generates the two-part mould, which is made of a gypsum slurry material. The mould is removed from the pattern and baked to remove the moisture. The molten metal is poured into the mould and allowed to cool. The mould is broken to remove the part (Figure 3.8(a)).

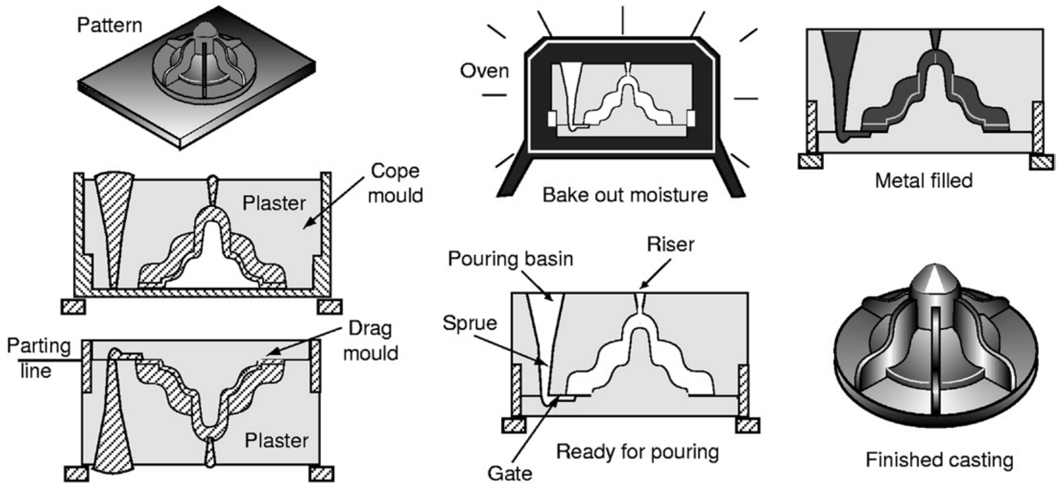

Figure 3.8(a): Plaster Mould Casting.

Materials

- Limited to low melting temperature metals, i.e. aluminium, copper, zinc and magnesium alloys, due to degradation of the plaster mould at elevated temperatures.
- Tin and lead alloys are sometimes processed.

Process Variations

- Patterns can be made from: metal, plaster, wood or thermosetting plastic. Wood has a limited life due to water absorption from the plaster slurry.
- Composition of plaster slurry varies. Additives are sometimes used to control mould expansion and fibres added to improve mould strength.

Economic Considerations

- Production rates of up to 10/h typical.
- Lead times can be several days to weeks.

- Material utilisation is high.
- Low scrap losses. Waste is recycled.
- Mould destroyed in removing casting.
- Easy to change design during production.
- Suitable for small batches of 100 and medium-volume production.
- Tooling costs are low to moderate.
- Equipment costs are moderate.
- Direct labour costs are moderate to high. Some skilled operations necessary.
- Finishing costs are low. Little finishing required except grinding for gate removal and sanding of parting line.

Typical Applications

- Pump impellers.
- Waveguide components (for use in microwave applications).
- Lock components.
- Gear blanks.
- Valve parts.
- Moulds for plastic and rubber processing, i.e. tyre moulds.

Design Aspects

- Moderate to high complexity possible.
- Possible to make mould from several pieces.
- Deep holes are not recommended.
- Sharp corners and features can be cast easily.
- Bosses and undercuts are possible with little added cost.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Cored holes greater than 13 mm diameter.
- Where machining is required, allowances of up to 0.8 mm should be observed.
- Draft angles from 0.5° to 2° preferred, but can be zero.
- Minimum section ranges from 0.8 to 1.8 mm, depending on material used.
- Sizes range from 25 g to 50 kg in weight. However, castings up to 100 kg have been made.

Quality Issues

- Little or no distortion on thin sections.
- Plaster mould has low permeability and can create gas evolution problems.
- Moderate to high porosity obtained.
- Mechanical properties are fair.
- Surface detail good.

- Surface roughness is in the range 0.8–3.2 μm Ra.
- A process capability chart showing the achievable dimensional tolerances is provided (Figure 3.8(b)). An allowance of approximately ±0.25 mm should be added for dimensions across the parting line.

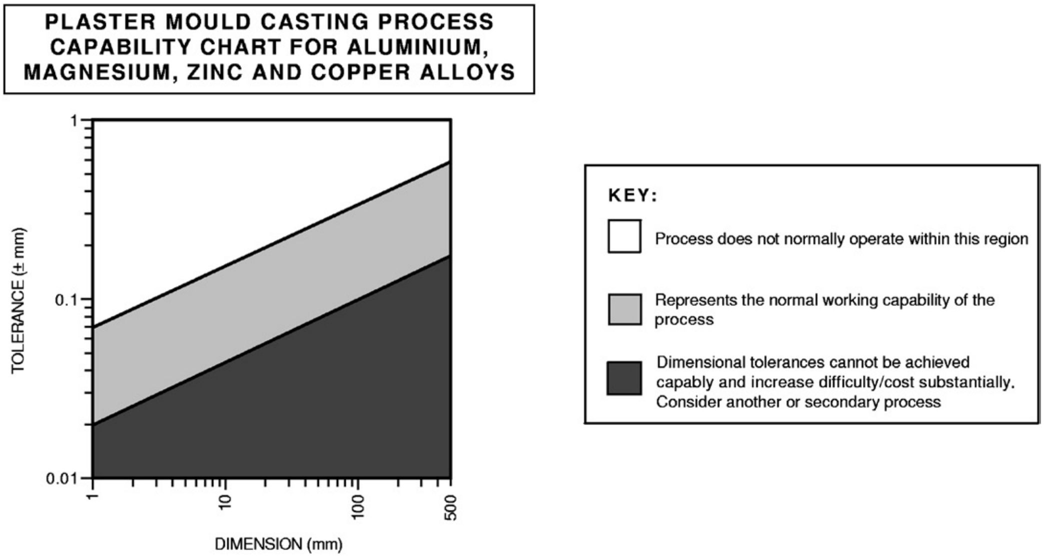

Figure 3.8(b): Plaster Mould Casting Process Capability Chart.

3.9 Squeeze Casting

Process Description

Combination of casting and forging. Molten metal fills a preheated mould from the bottom and during solidification, the top half of the mould applies a high pressure to compress the material into the final desired shape (Figure 3.9). Also known as liquid metal forging and load pressure casting.

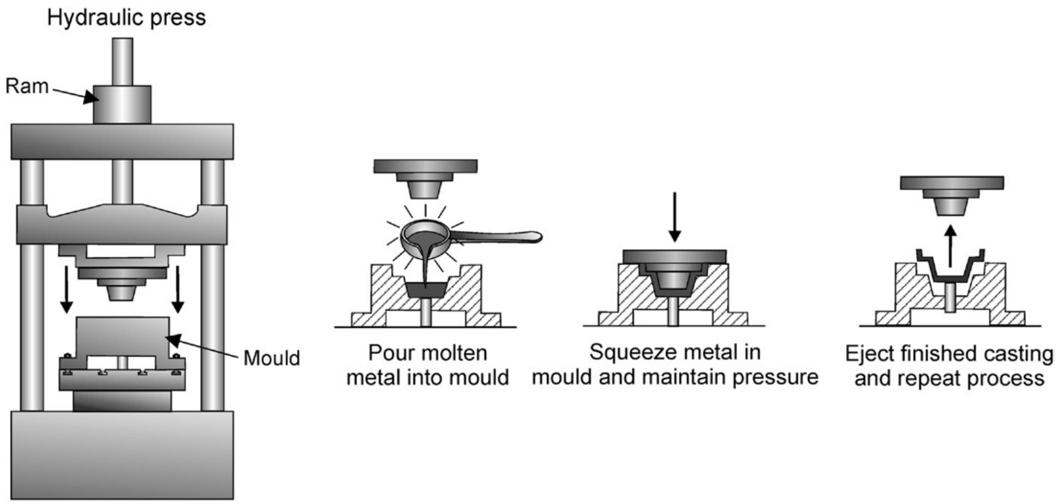

Figure 3.9: Squeeze Casting.

Materials

Typically non-ferrous metals, but occasionally, ferrous alloys.

Process Variations

Pouring can be performed automatically.

Economic Considerations

- Production rates low to medium.
- Cycle times can be of the order of minutes depending on size.
- Lead time is moderate to high.
- Material utilisation is excellent. Near-net shape achieved. No waste.
- High degree of automation possible, but little flexibility.
- Economically viable for medium to high production volumes of 10,000+.

- Tooling costs are high due to complexity.
- Equipment costs are high.
- Direct labour costs are low to moderate.
- Finishing costs are very low.
- Used to minimise or eliminate secondary processing.

Typical Applications

- Aerospace components.
- Suspension parts.
- Steering components.
- Brake rotors.
- Engine pistons.
- Wheels.
- Bearing housings.

Design Aspects

- Complex geometries possible.
- Retractable and disposable cores used to create complex internal features.
- Large variations in cross-section possible, but gradual transition recommended.
- Undercuts, bosses, holes and inserts possible.
- Ribs, pockets and features can improve local sectional properties.
- Placing of parting line important, i.e. avoid placement across critical dimensions.
- Machining allowances are usually in the range 0.6–1.2 mm.
- Draft angle ranges from 0.1° to 3°, depending on section depth.
- Maximum section = 200 mm.
- Minimum section = 6 mm.
- Minimum dimension = 20 mm diameter.
- Sizes range from 25 g to 4.5 kg in weight.

Quality Issues

- Low gas porosity, shrinkage and defect levels compared to other casting processes.
- Adequate process control is important, i.e. metering of molten metal, pressures, solidification times, tooling temperatures, etc. to avoid porosity.
- Defects can be minimised through correct die design, e.g. multiple gate system, by increasing die temperature, or by decreasing delay time before die closure.
- Abrupt changes in section also tend to create shrinkage and porosity problems.
- Low-speed mould filling minimises splashing, but increases cycle times.
- Accurate metering of molten metal required to avoid flashing.

- Excellent mechanical properties can be obtained, similar to forging.
- Graphite releasing agent and ejector pins commonly used to aid removal of finished part.
- Castings can be heat treated.
- Surface detail is good.
- Surface roughness is in the range 1.6–12.5 μm Ra.
- Achievable dimensional tolerances are approximately ±0.15 up to 25 mm, ±0.3 up to 150 mm. Allowances of ±0.25 mm should be added for dimensions across the parting line.