Lecture # 4

22 September 2020

Solidification Processing

Classification

FULL MOULD (EVAPORATIVE PATTERN) CASTING

PROCESS

Expendable mould and pattern

A refractory coating is applied to a volatile or combustible pattern which is used in a sand mould. The pattern is destroyed by the molten metal.

SHAPE

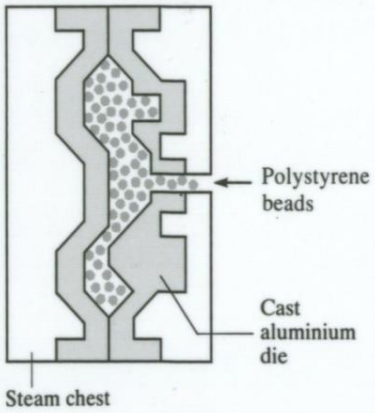
3D

Very complex shapes possible.

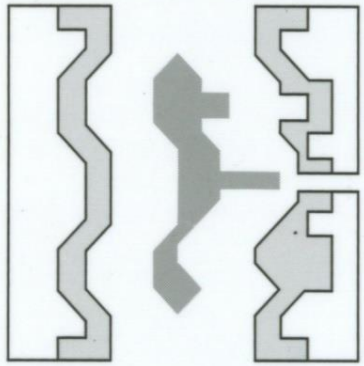
MATERIALS

Metals

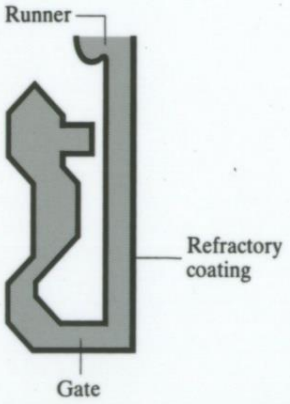
Nonrefractory metals with casting temperatures high enough to vaporize the pattern.



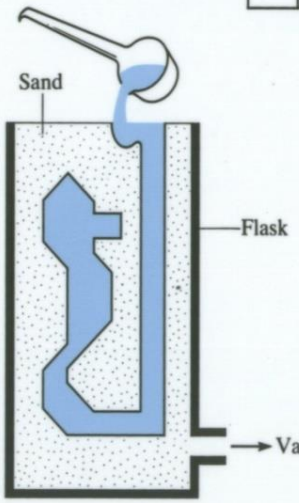
1. Inject polystyrene beads into a heated aluminium die. Pass steam through mould to fuse and expand polystyrene beads to form solid pattern.

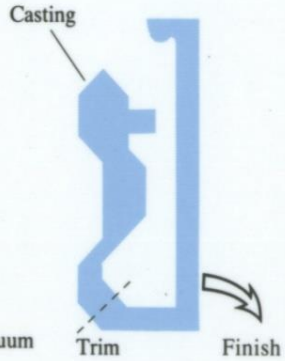


2. Cool die, open to eject pattern.



3. Glue on additional runners and risers where necessary. Cover pattern with refractory slurry and dry to form a refractory coating.





4. Place pattern in a 'flask' of loose dry unbonded sand and consolidate by vibration. Apply vacuum to flask and pour metal. Cool, remove casting and recycle sand.

CYCLE TIME

Long due to process complexity. Multiple moulds increase production rate.

QUALITY

Normal sand casting defects. Surface texture similar to that of pattern.

FLEXIBILITY

Ideal for the manufacture of one-offs.

MATERIALS UTILIZATION

Pattern material entirely wasted. Metal usage poor due to runners etc.

OPERATING COST

All equipment involved is rudimentary and process is very cheap to operate.

INVESTMENT CASTING

PROCESS

Expendable mould and pattern

A ceramic shell (investment) is slip cast around a wax pattern. Wax is melted and molten metal cast into the investment which is broken up to remove the casting.

SHAPE

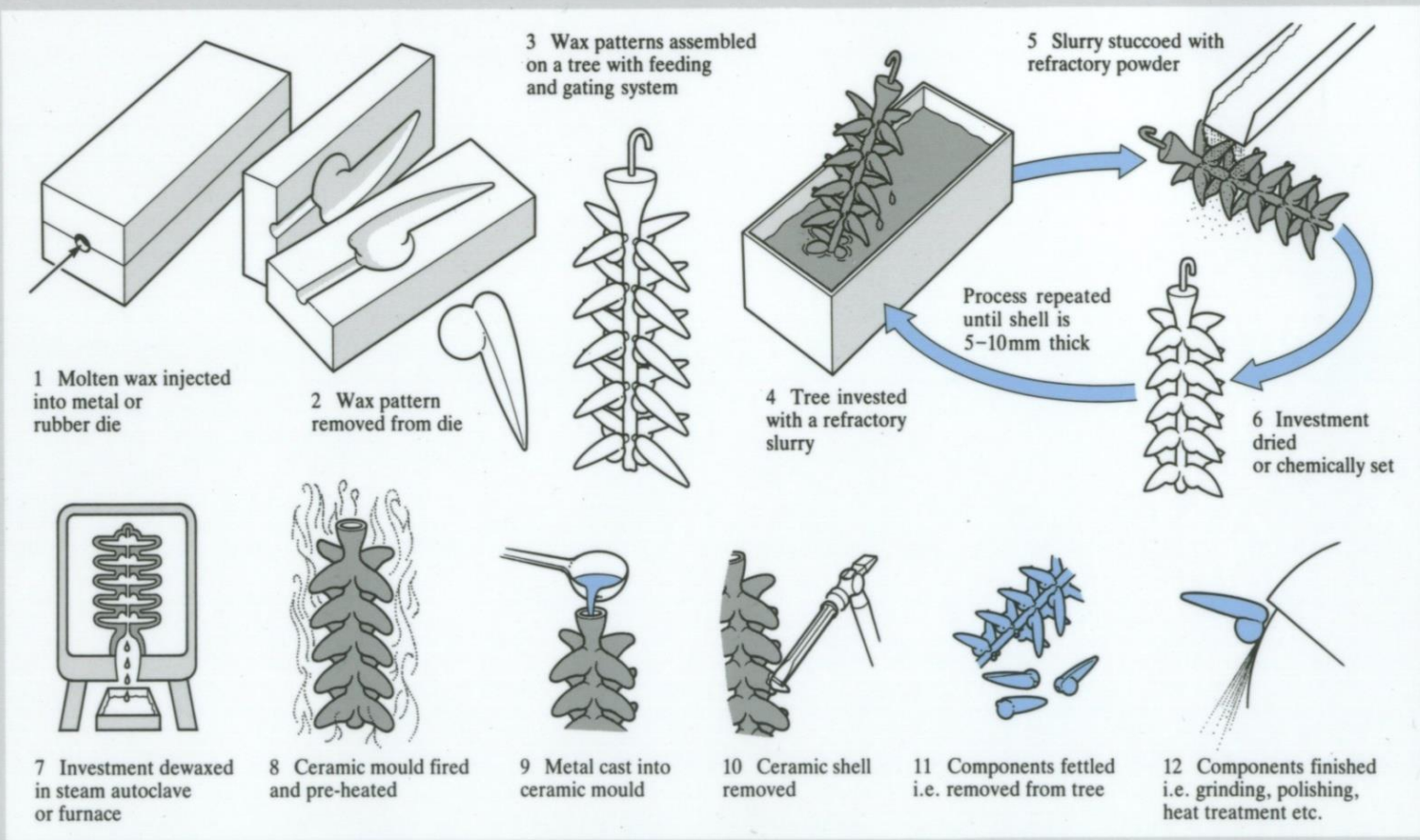
3D

Best for relatively small, complex 3D components. Re-entrant angles possible.

MATERIALS

Metals

Suitable for most metals. Reactive metals can be cast under vacuum.



CYCLE TIME

Limited by rate of heat transfer out of the casting. Production rates low because of process complexity. Increased by using multiple moulds and patterns.

QUALITY

Surface texture good. Higher mould temperatures decrease porosity but produce coarse microstructures.

FLEXIBILITY

Moderately high because of the ease of production of patterns.

MATERIALS UTILIZATION

Near net shape process with little material contained in feeding systems. Wax recycled, investment lost.

OPERATING COST

Equipment costs can be high especially where reactive alloys are concerned. Labour costs are high due to the many stages in the process.

PRESSURE DIE CASTING

PROCESS

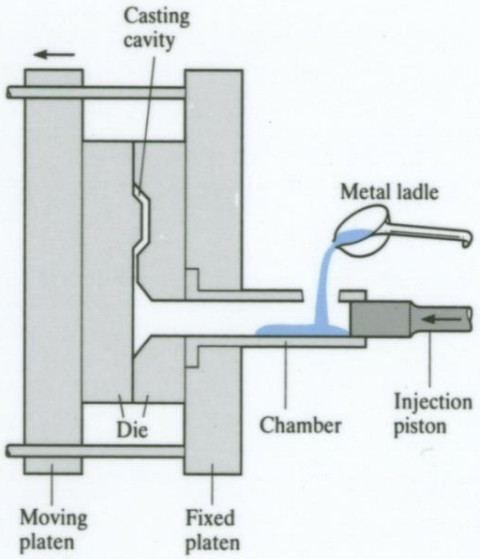
Permanent mould
Molten metal is forced into a water-cooled metal mould (die) through a system of sprues and runners. The metal solidifies rapidly and the casting is removed with its sprues and runners.

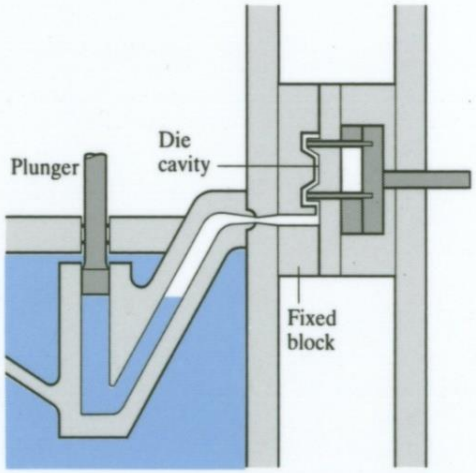
SHAPE

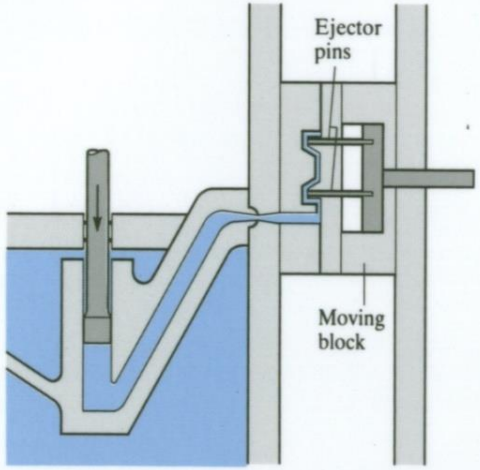
3D solid
Used for complex shapes and thin sections. Cores must be simple and retractable.

MATERIALS

Light alloys
High fluidity requirement means low melting temperature eutectics usually used. Hot chamber method restricted to very low melting temperature alloys (e.g. Mg and Zn).

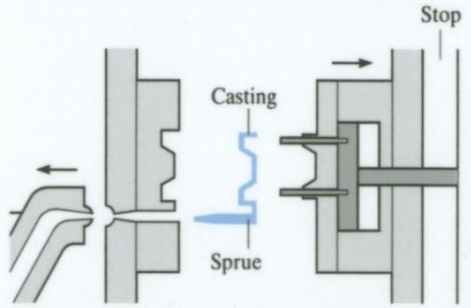






Cold-chamber high pressure die casting
Molten metal is poured into a cold shot chamber. A high pressure plunger forces metal into the single or multi-die cavity.

Hot chamber high pressure die casting
A gooseneck hot chamber is submerged in a pot of molten metal. Metal is injected directly from the pot via the gooseneck.



CYCLE TIME

Solidification time is typically < 1 s so cycle is controlled by time taken to fill mould and remove casting.

QUALITY

Good surface texture but turbulent mould filling produces high degree of internal porosity.

FLEXIBILITY

Tooling dedicated so limited by machine setting up time.

MATERIALS UTILIZATION

Near net shape process but some scrap in sprues, runners and flash which can be directly recycled.

OPERATING COST

High, since machine and moulds are expensive.

CENTRIFUGAL CASTING

PROCESS

Permanent mould
Molten metal is introduced into a sand- or copper-lined, cylindrical steel mould which is rotated about its long axis, distributing the metal over its inner surface.

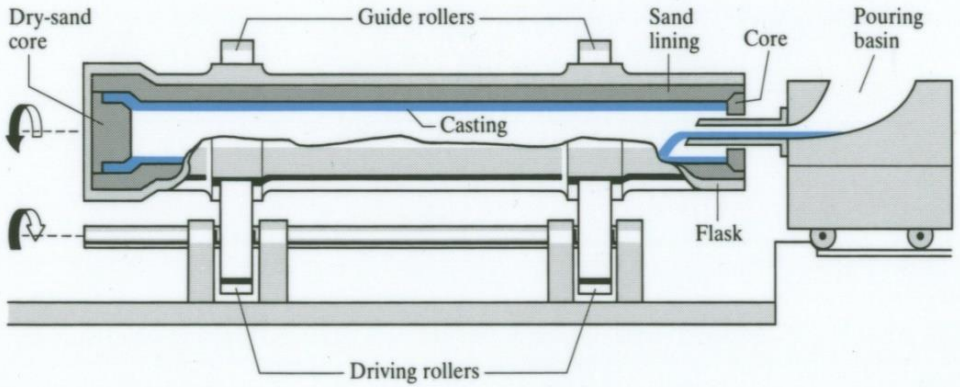
SHAPE

3D hollow
Technique used to produce relatively long, hollow objects without the need for cores.

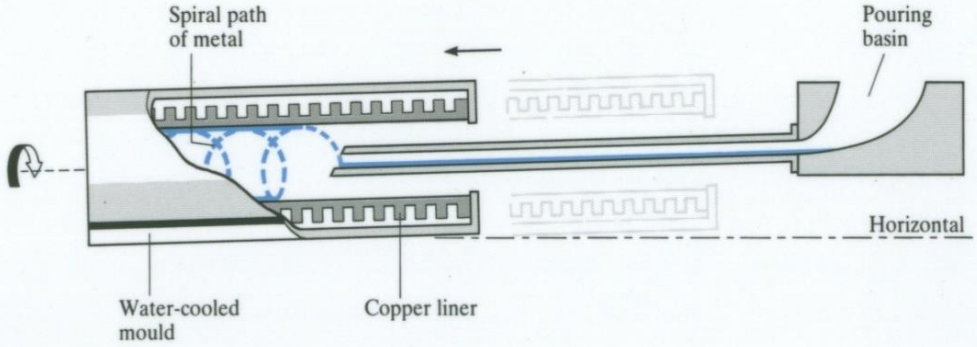
MATERIALS

Metals
Metals excluding refractory and reactive metals.

Sand mould casting



Metal mould casting



CYCLE TIME

Determined by the rate of introduction of metal into the mould and the rate of solidification of the metal. The latter is lower for sand-lined moulds.

QUALITY

Porosity and nonmetallic inclusions migrate towards the inner surface because of their lower density, giving a high quality outer surface.

FLEXIBILITY

Setting up times are relatively short.

MATERIALS UTILIZATION

Absence of runners and risers leads to near 100% use of material.

OPERATING COST

Equipment is relatively simple and can cost little. Increased complexity of water-cooled copper-lined moulds more costly.

INJECTION MOULDING

PROCESS

Permanent mould

Molten polymer is forced at high pressure into a cool metal mould. The polymer solidifies under pressure and the moulding is removed.

SHAPE

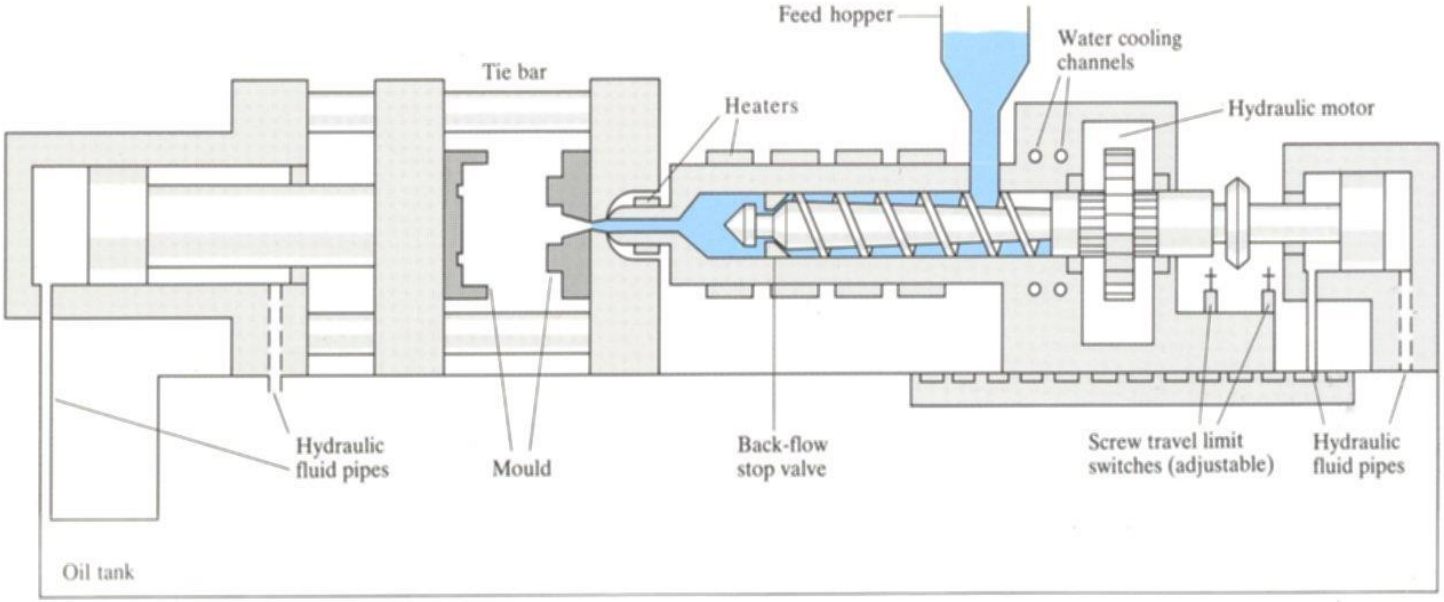
3D

Complex shapes although thick sections are problematical. Small re-entrant angles possible if material flexible.

MATERIALS

Polymers

Mainly thermoplastics, also rubbers, thermosets and composites.



CYCLE TIME

Limited by solidification time and demoulding time.

QUALITY

Can be reasonable but normally compromised in the pursuit of high production rates.

FLEXIBILITY

Restricted by mould changeover and machine setting up time.

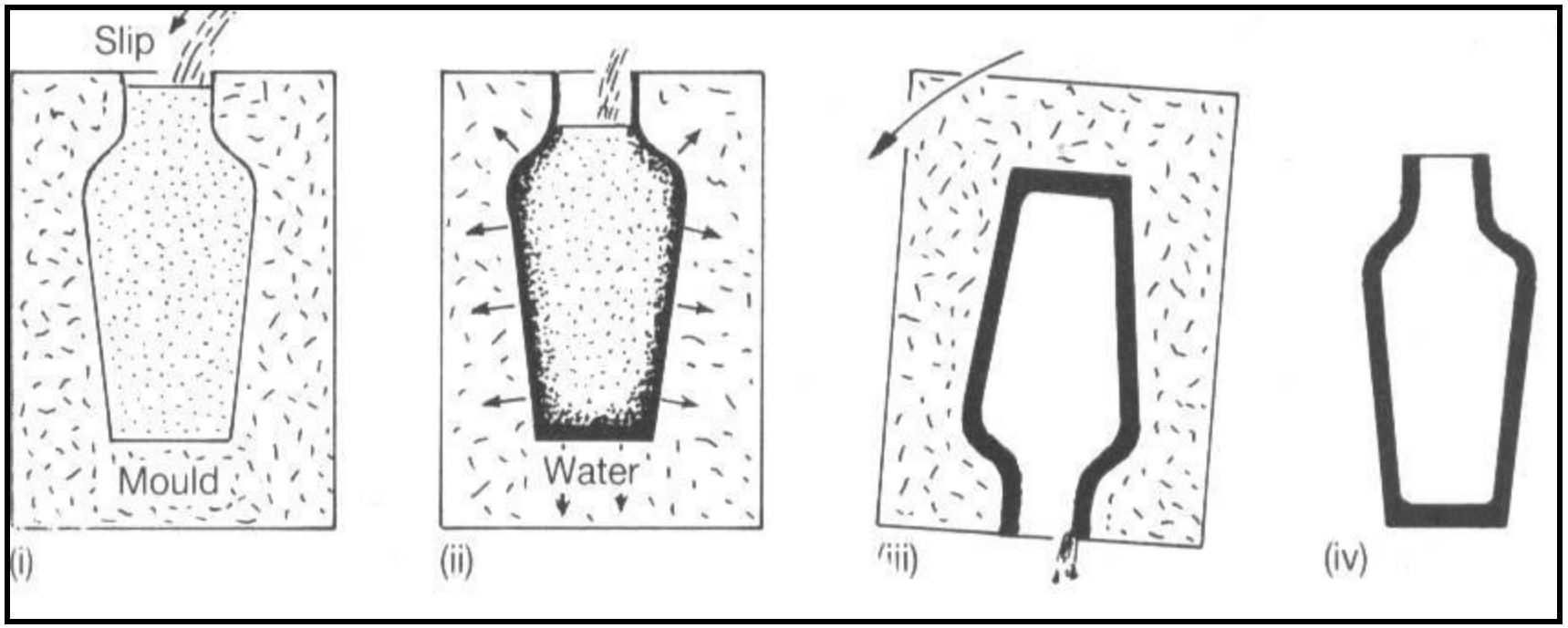
MATERIALS UTILIZATION

Scrap in sprues and runners. Thermoplastics can be recycled with some degradation of properties.

OPERATING COST

High due to cost of machines and moulds.

Slip-Casting



(i) Slip is first poured into an absorbent mould
(ii) a layer of clay forms as the mould surface absorbs water
(iii) when the shell is of suitable thickness excess slip is poured away
(iv) the resultant casting

SLIP CASTING

PROCESS

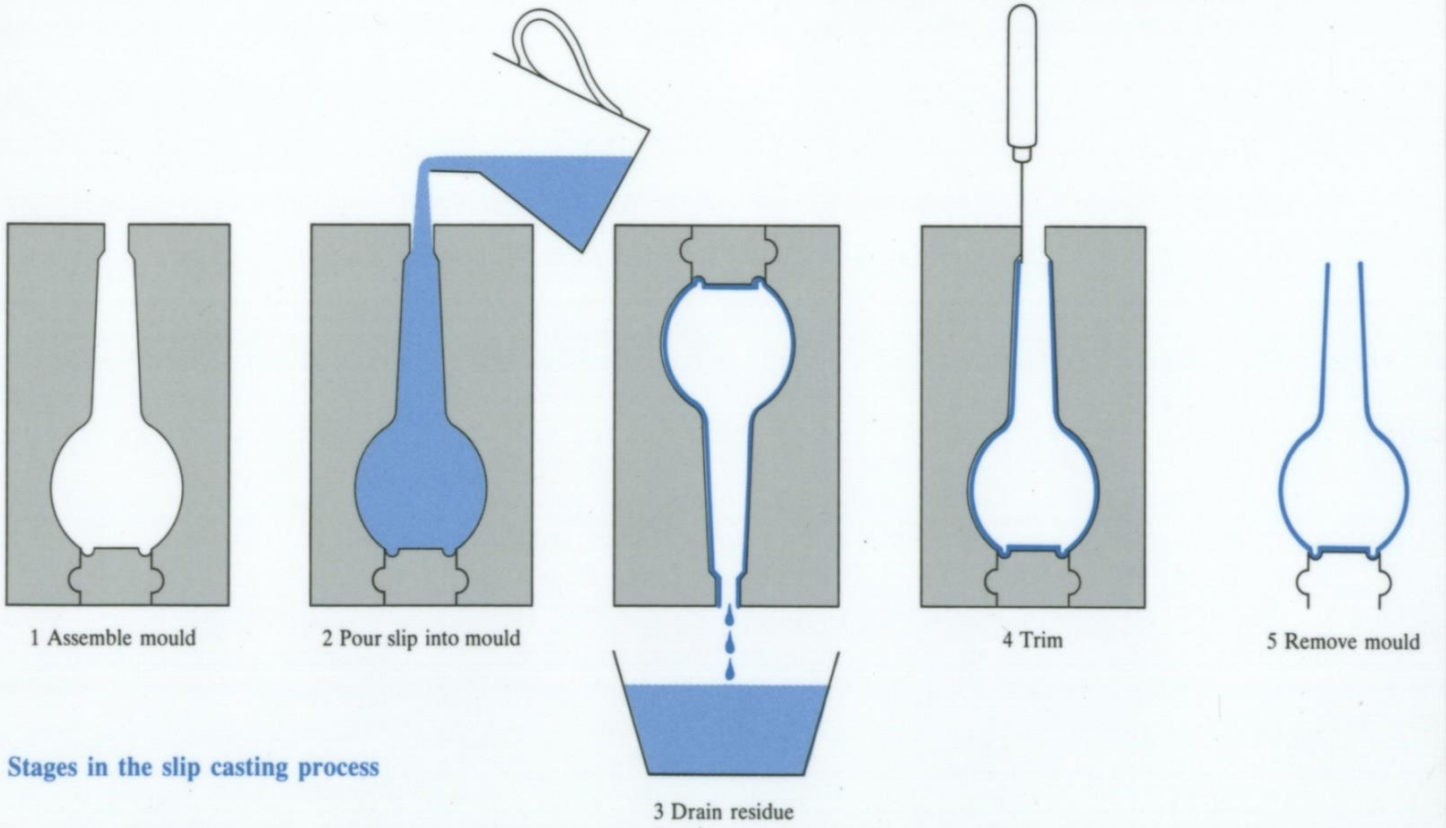
Powder processing
A powder slurry is introduced into a porous mould which extracts the liquid from the slurry, forming a green compact which is then sintered at elevated temperature.

SHAPE

3D
Complex solid shapes with re-entrant angles.

MATERIALS

Ceramics
Mainly used for domestic ceramics. Some engineering ceramics.



Stages in the slip casting process

CYCLE TIME

Production of green compact and sintering is time consuming. Multiple moulds increase production rate.

QUALITY

Surface texture reasonable if product subsequently glazed. Porosity inevitable.

FLEXIBILITY

Moulds cheap. Sintering equipment not dedicated.

MATERIALS UTILIZATION

Near net shape process. 100% material utilization.

OPERATING COST

Machinery and tooling relatively inexpensive.

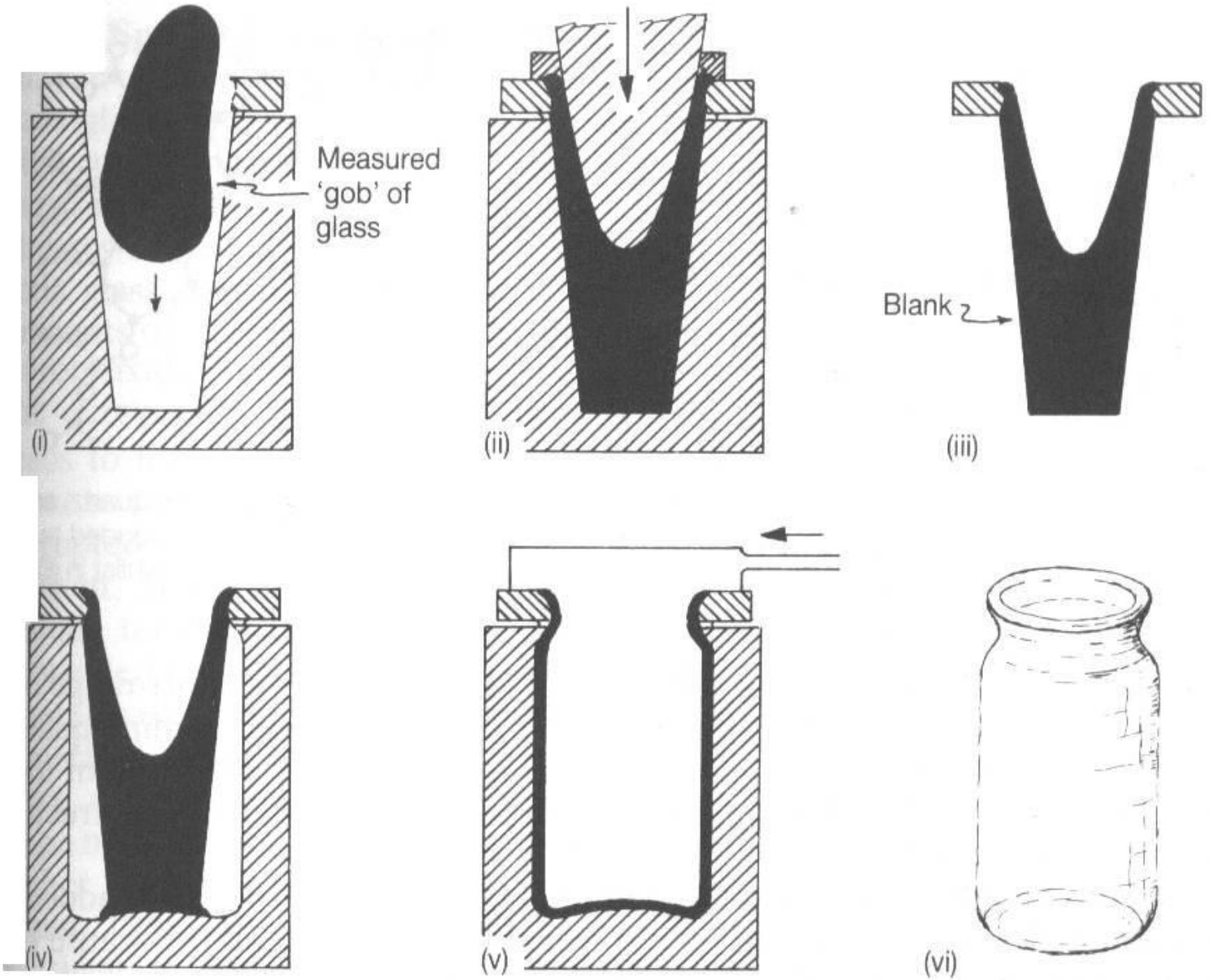


Fig. A 'press-and-blow' method for producing a jam jar.

Float-Bath Method for the Manufacture of Flat Glass