



Aalto University
School of Engineering

Casting methods

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Overview

- **Lost mould**

- Permanent pattern

- *Sand casting*

- Manual shaping

- Mechanical shaping

- *Shell moulding*

- *Ceramic moulding*

- Lost pattern

- *Investment casting*

- Lost-wax casting

- Other lost pattern types, PMMA-PLA-ABS etc.

- *Lost foam casting*

- *Vacuum casting*

- **Permanent mould**

- Without pattern

- Die casting

- Gravity die casting

- Centrifugal casting

- Injection moulding

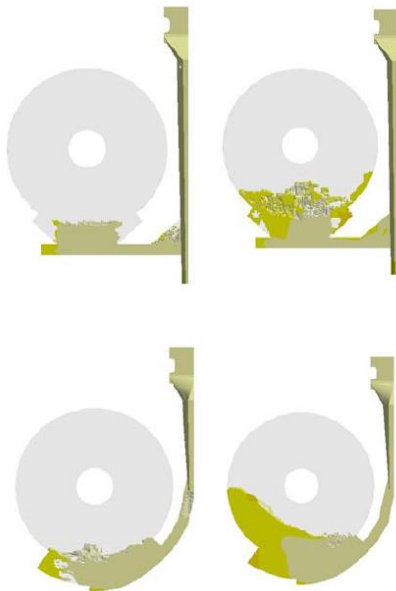
- Continuous casting

- Strip casting

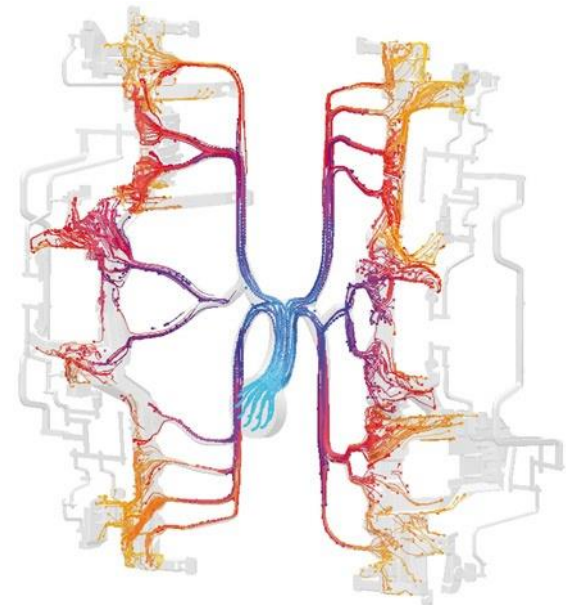
Casting

Filling mold cavities with molten metal, solidified by cooling

Gating variations, DISAMATIC gravity casting



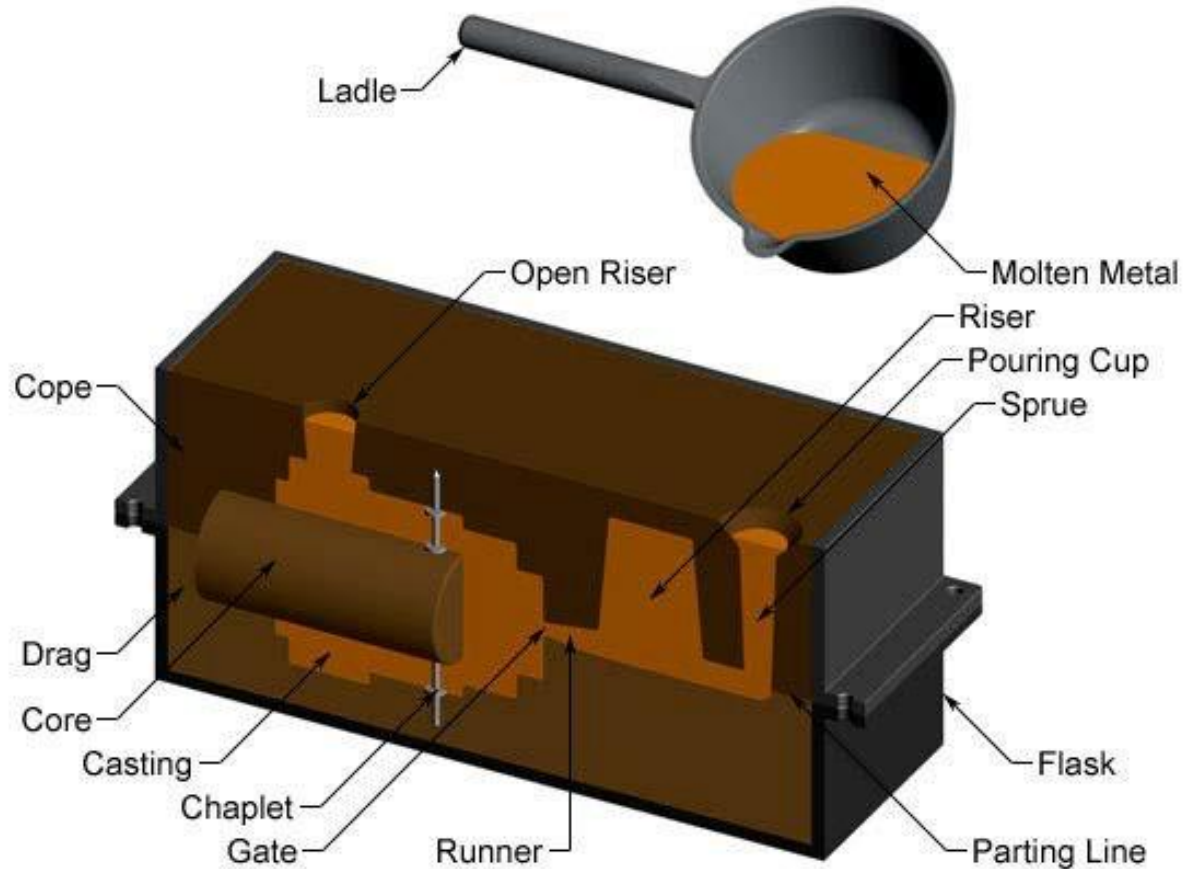
Melt tracer lines, High Pressure Die Casting (HPDC)



Sand casting

Lost mould, permanent pattern

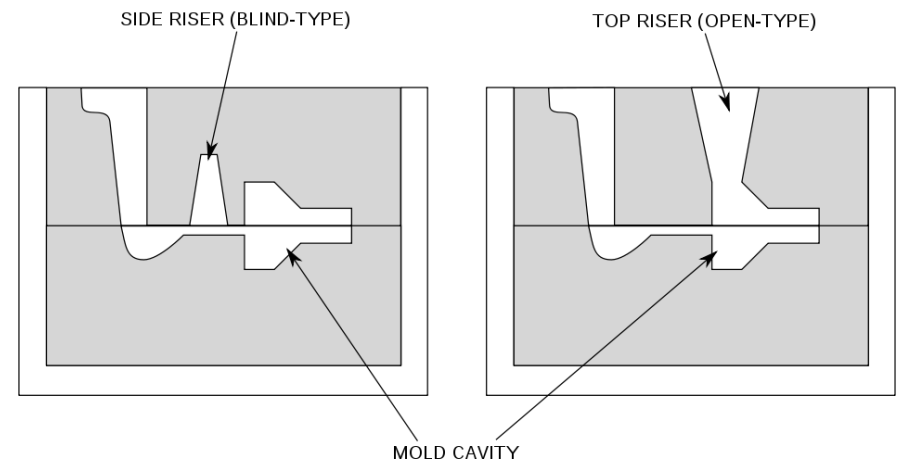
- Cope
- Drag
- Core
- Gating system
 - Riser
 - Sprue



Sand casting

Riser

- **Reservoir of molten metal**
 - Prevent cavities due to solidification shrinkage
 - Liquid is less dense than solid
- **Controlling of solidification direction**
 - Preferably towards riser
- **Air flow while casting**
 - Open-riser

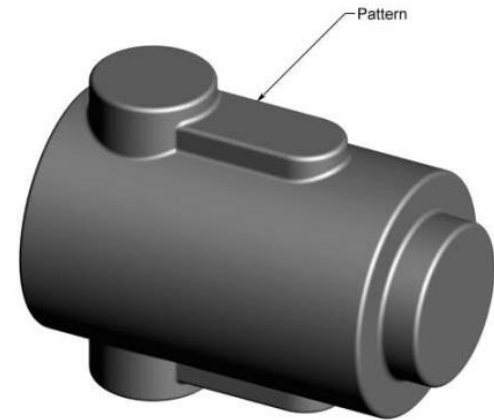


Sand casting

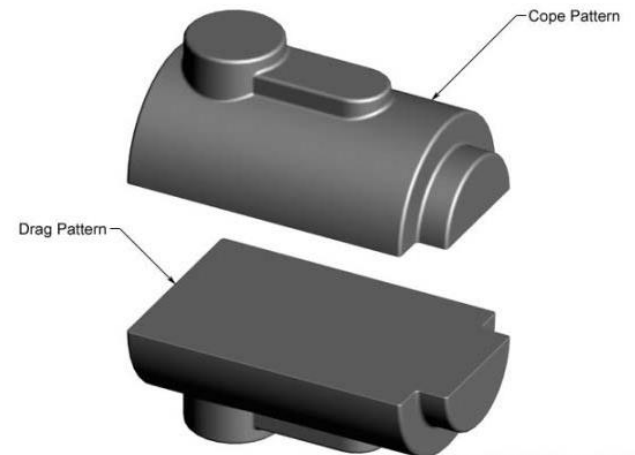
Pattern

- **Solid pattern**
 - geometrically simple parts
 - low quantities

- **Split pattern**
 - geometrically complex parts
 - moderate quantities



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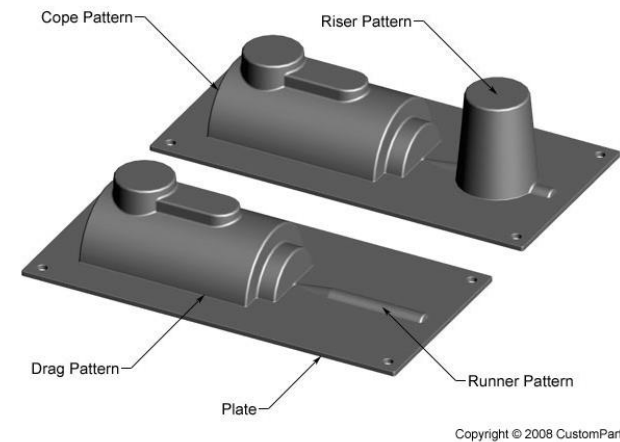
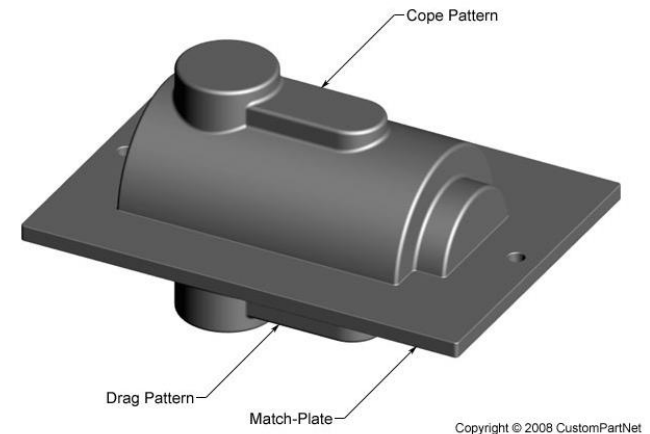
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Sand casting

Pattern

- **Match-plate pattern**
 - Larger quantities
 - Often in automated processes

- **Cope and drag Pattern**
 - When a match-plate pattern would be too heavy
 - Larger quantities
 - Often in automated process



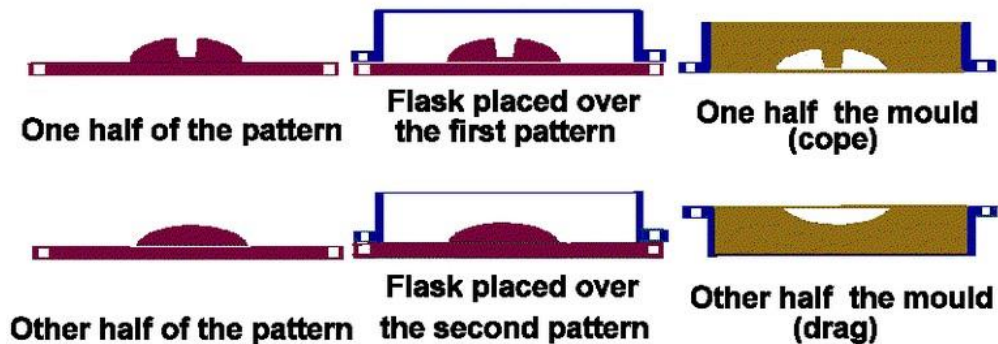
Sand casting

Cope pattern



Sand casting

Mold making



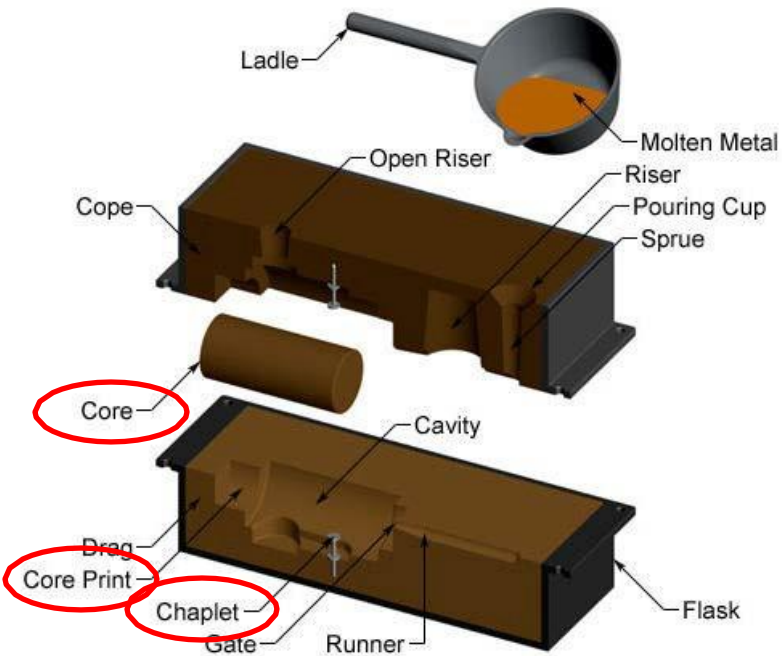
One type of green sand, example:

- Sand: Silica sand, SiO_2
- Binder: Bentonite clay
- Additives: Water 3 – 4 %



Sand casting

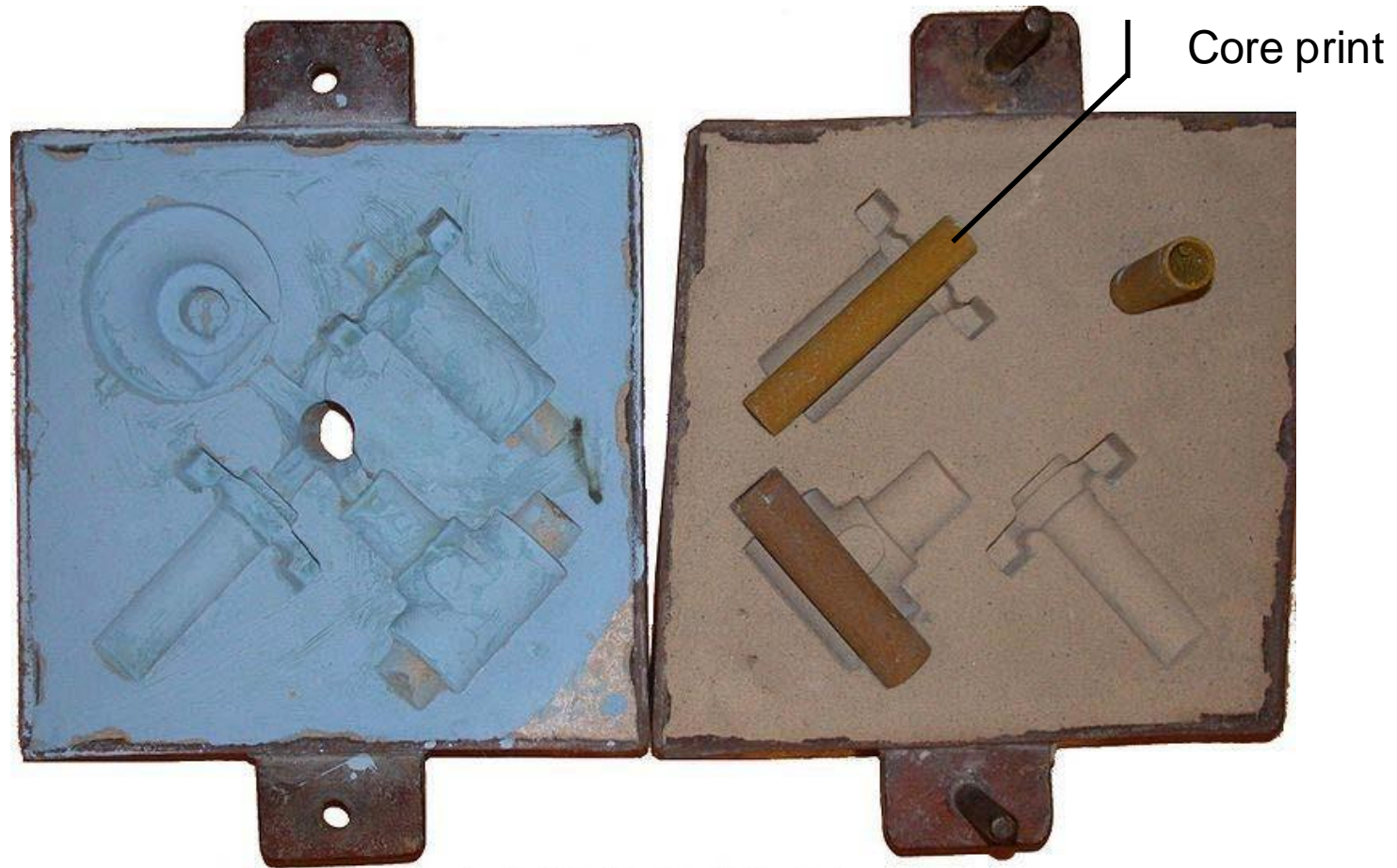
Insert cores



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Sand casting

Assembly



Sand casting

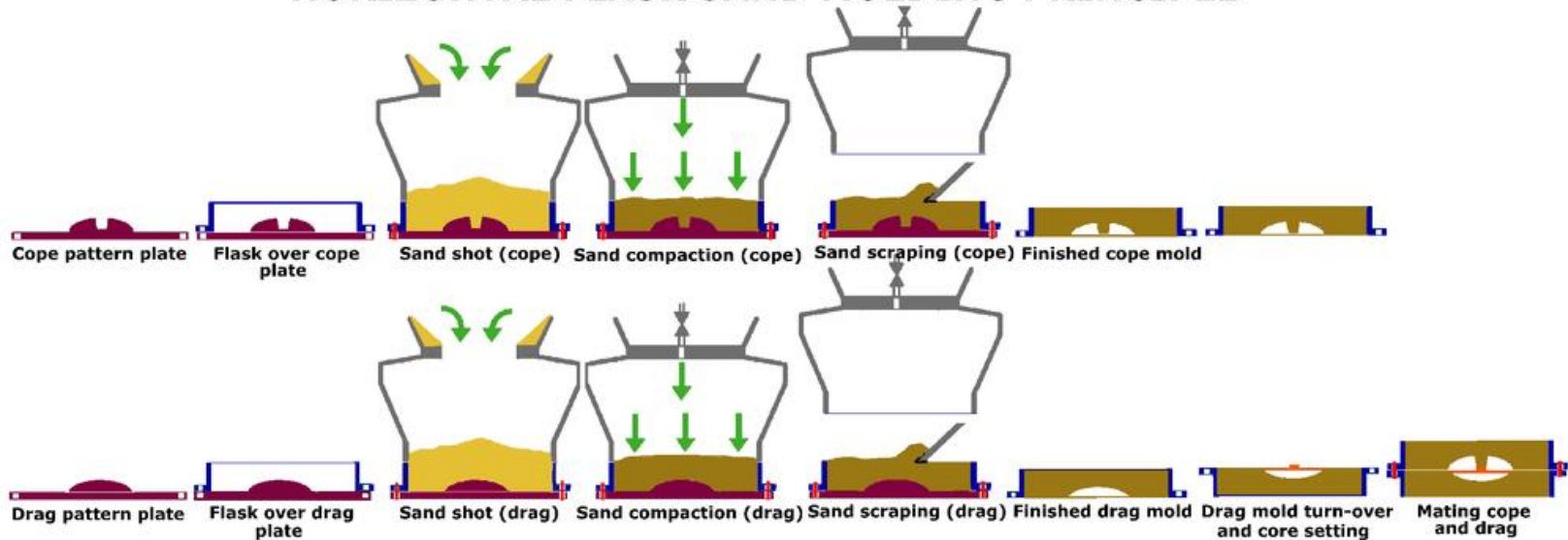
Casting



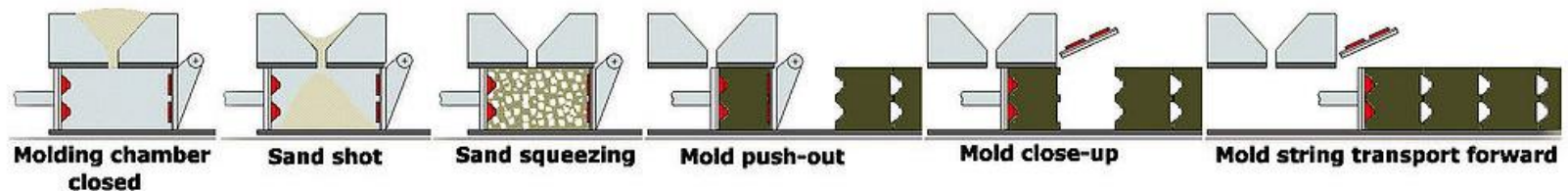
Sand casting

Mechanical shaping

HORIZONTAL FLASK SAND MOLDING PRINCIPLE



DISA SAND MOLDING PRINCIPLE



Sand casting

Mechanical shaping



Sand casting

- **Advantages**

- Very large parts
- Complex shapes
- Many material options
- Low tooling and equipment costs
- Recyclable scrap
- Short lead time possible

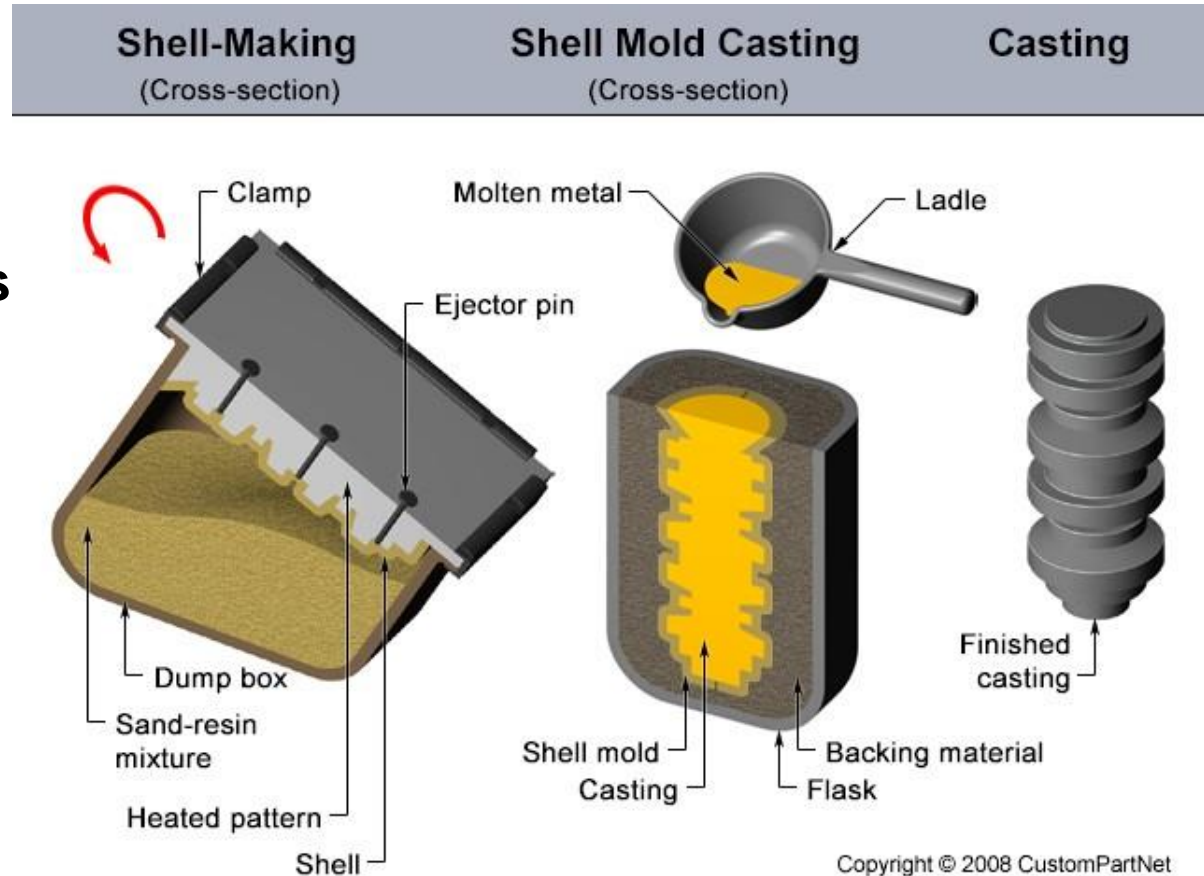
- **Disadvantages (?)**

- Some porosity possible
- Moderate surface finish and tolerance
- Secondary machining often required
- Low production rate
- High labor cost
- Need for cores

Shell moulding

Lost mould, permanent pattern

- Heated pattern
- Resin in mixture cures
- Thin-walled shell



Shell moulding

- **Advantages**

- Complex shapes and fine details
- Very good surface finish
- Little scrap generated

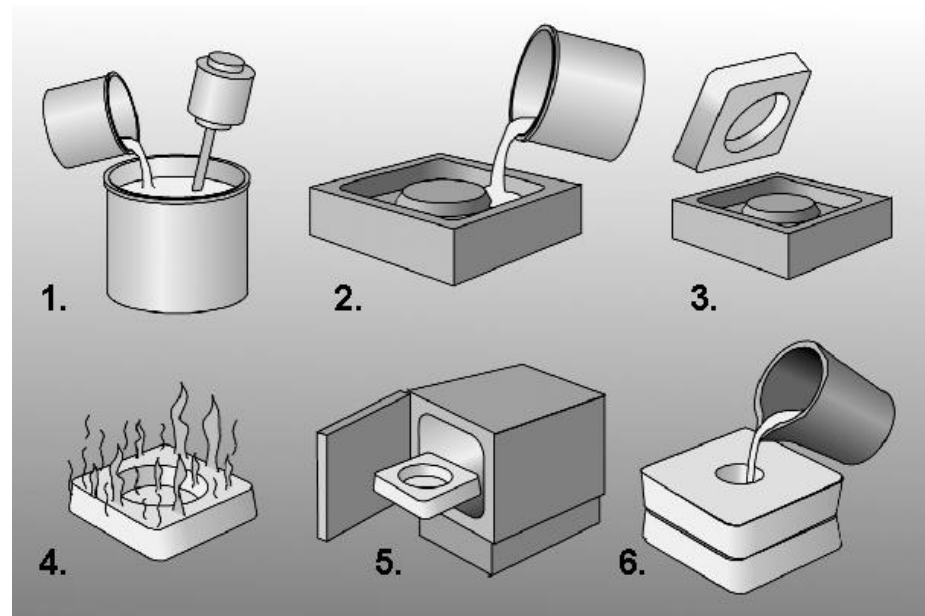
- **Disadvantages**

- High equipment costs
- High tooling costs
- Environmental aspects

Ceramic moulding

Lost mould, permanent pattern

- **Permanent pattern**
- **Ceramic slurry**
 - Binder
 - Refractory powder
- **Mould forming at low temperatures**
- **Shaw-method**
 - burn
- **Unicast-method**
 - evaporate



Ceramic moulding

- **Advantages**

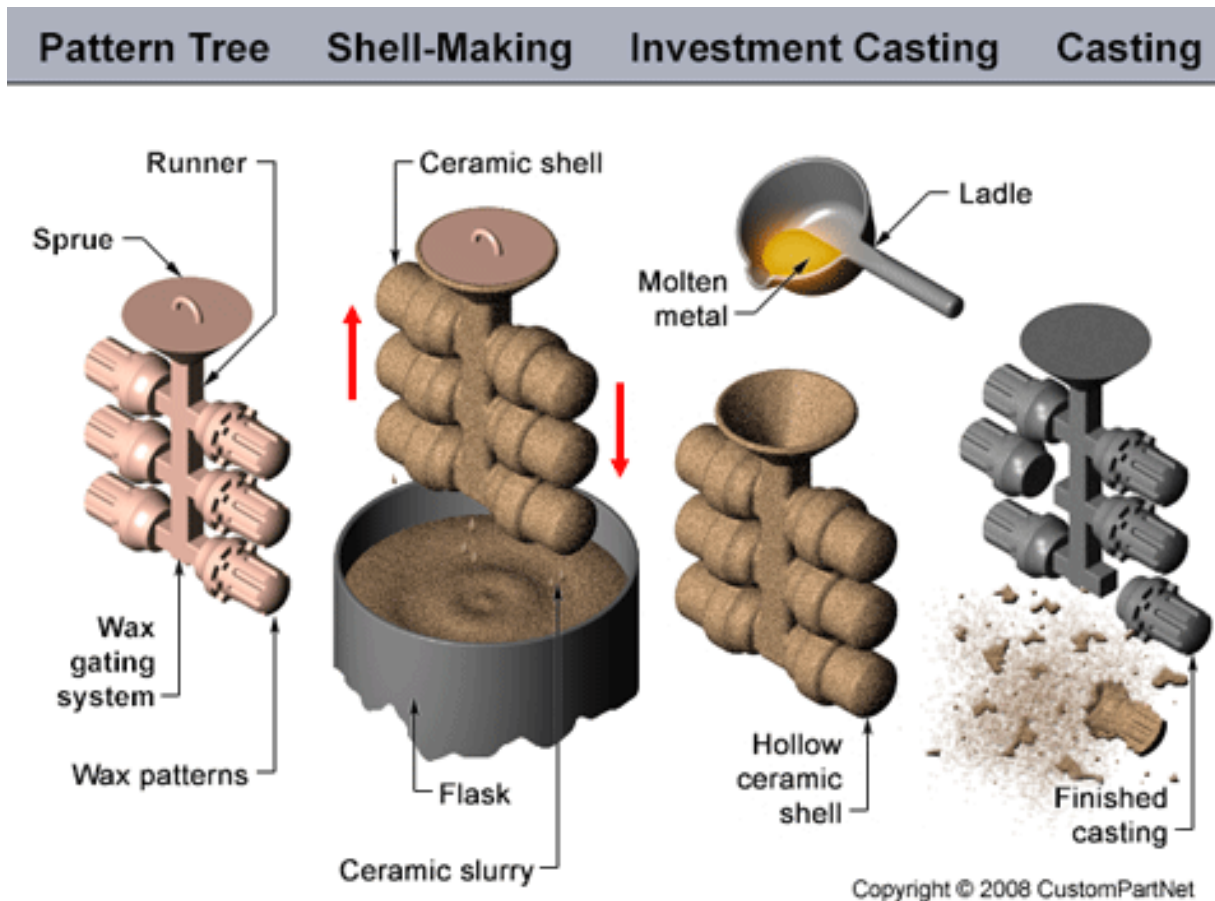
- For high temperature castings
- Very good surface finish
- Very accurate
- No casting skin

- **Disadvantages**

- Mold must be baked
- Expensive

Investment casting

Lost mould, lost pattern



Investment casting

Assembling a wax pattern to a pattern tree

- Other possible pattern types include 3D-printed parts



Building a ceramic shell

- Ceramic slurry
- Sand and fireclay
- Drying



Investment casting

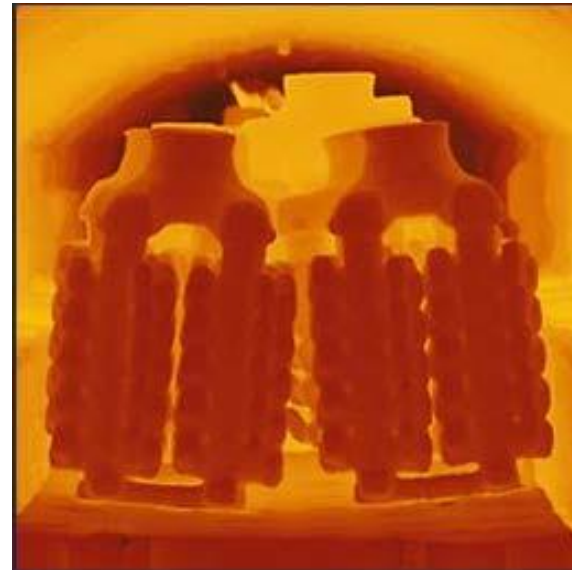
Melting out patterns

- Hollow ceramic shell



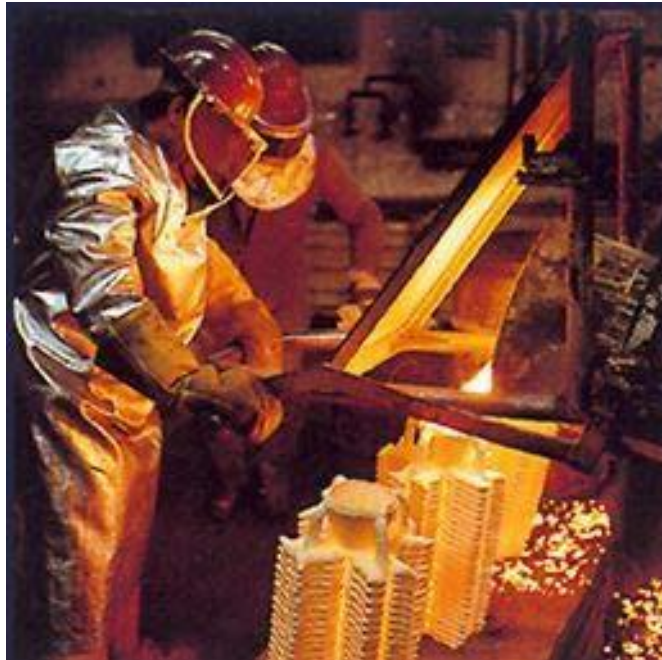
Firing hollow ceramic shells

- Sintering process
- Over 1000 °C



Investment casting

Pouring into preheated shells



Breaking cast ceramic shells

- by vibration
- chemically



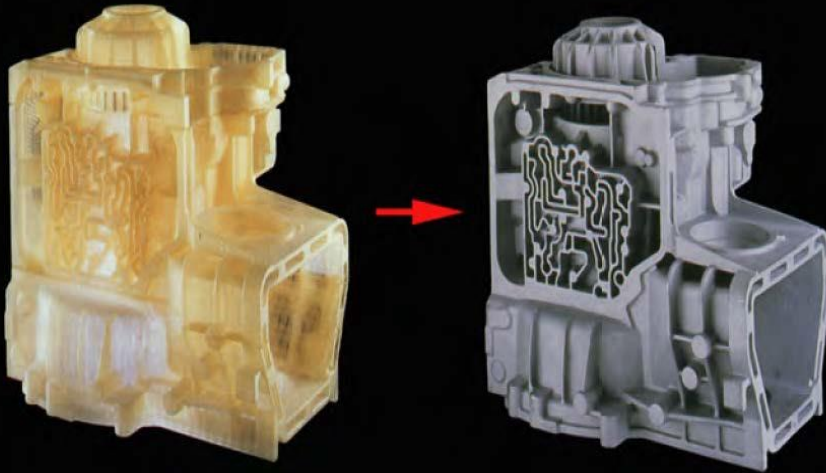
Investment casting

Automatic gearbox housing

- ENAC-AISiMg0.6
- Quick-Cast (Stereolithography SL)

Cover construction

- ENAC-AISi12
- Wax 3D-print



Investment casting

One-piece compressor stator

- 108 separate airfoils
- Courtesy Howmet Corp



Investment casting

Advantages

- Complex shapes and fine details
- Many material options
- High strength parts
- Very good surface finish and accuracy
- Little need for secondary machining
- CAD-models directly usable

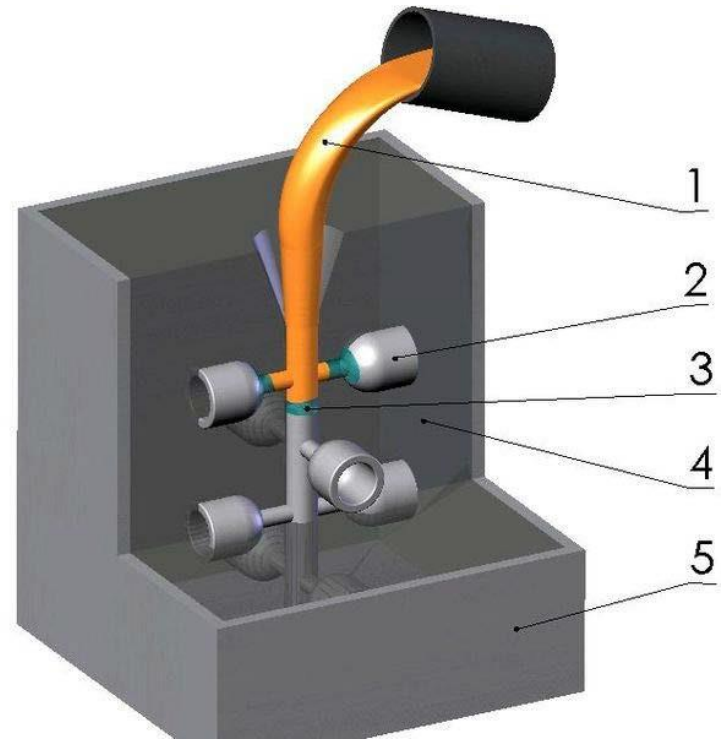
Disadvantages

- Time-consuming process
- High labor cost
- High tooling cost
- Long lead time possible

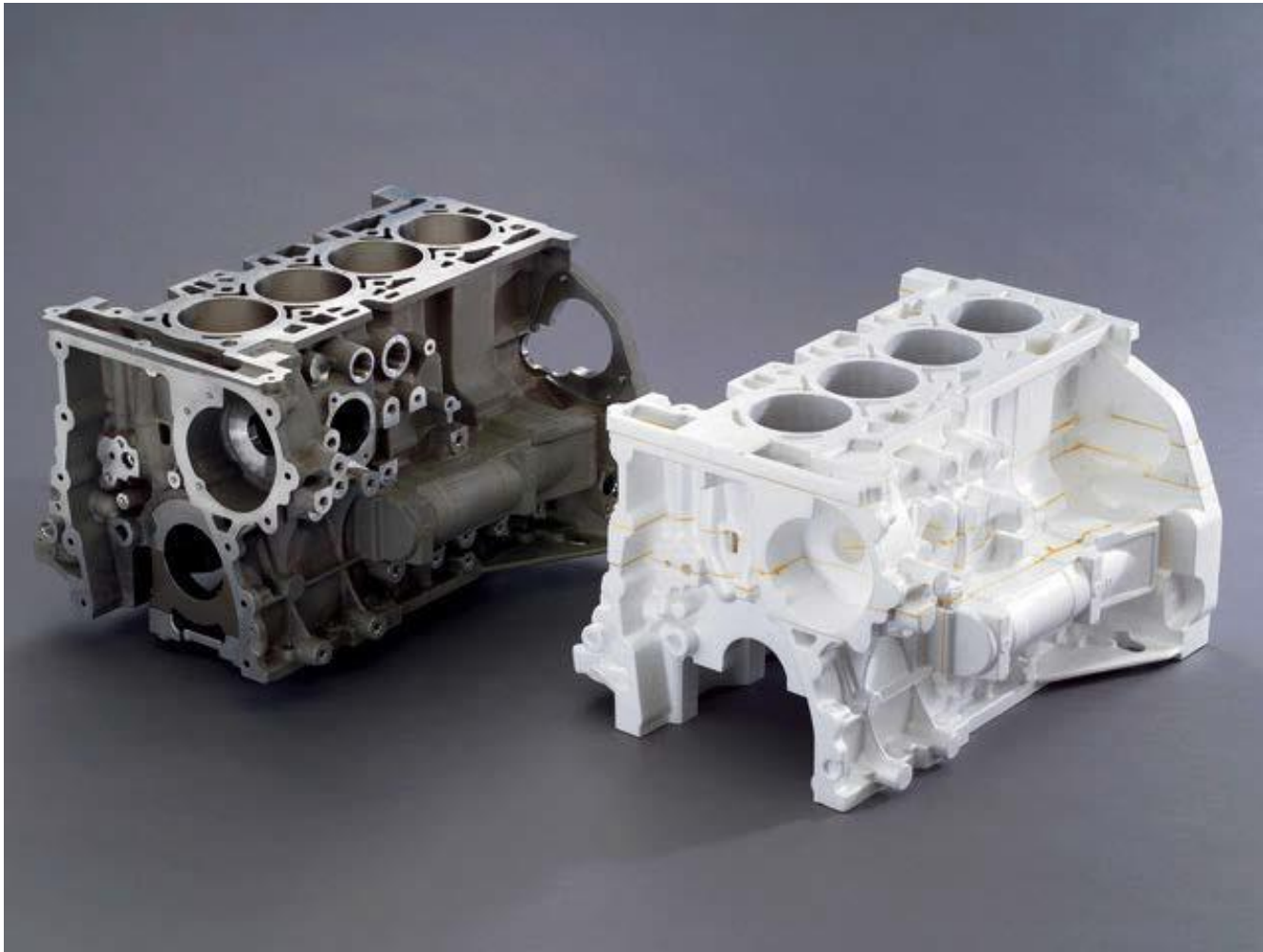
Lost foam casting

Lost mould, lost pattern

- **Polystyrene (foam) Pattern**
 - Sprayed refractory compound
- **No cavity**
- **Molten metal vaporizes foam**
 - Metal fills the resulting mold cavity



Lost foam casting



Lost foam casting

Advantages

- Complex shapes without cores
- Dimensionally accurate
- Excellent surface finish
- No drafts required
- No parting line (no flash)
- Natural directional solidification

Disadvantages

- High pattern costs
- Low strength of patterns
 - Easily damaged or distorted

Kaavausmenetelmä	Malli/kestomuottivarusteet ja -kustannukset	Valukappaleen koko tai paino	Sarja-suuruus	Valumetallit	Toleranssit	Muotoilun vapaus	Mallien/kestomuottien rakennemuutos
Käsin- ja sinkokaavaus	puisia, myös mallineet, 1	10 g...100 t	yksittäin, piensarjat	kaikki	CT 11-15	hyvä	helppo
Jäykkämuottikaavaus	puu, muovi, metalli, polystyrolia, 1	10 kg...100 t	yksittäin, sarjat	kaikki	CT 10-14	hyvä, polystyrolimalleilla erinomainen	helppo
Täysmuottikaavaus	polystyrolia, 1	10 kg...100 t	1-5 kpl	kaikki	CT 10-14	erinomainen	erittäin helppo
Keernamuotit	puu, muovi, metalli, 2	50 kg...100 t	yksittäin, sarjat	kaikki	CT 10-14	erittäin hyvä	helppo
Konekaavaus	puu, muovi, metalli, 3	10 g...1000 kg	>50 kpl	kaikki	CT 7-10	hyvä	helppo, metallimalliin kallista
Kuorimuottikaavaus	metalli 4	100g...50 kg yleensä max 0,8x0,8x0,5m	100-200 kpl	kaikki	CT 7-10	erittäin hyvä	kallis
Shaw- ja Unicastmenetelmät	puu, muovi, metalli (Al) 2	0,5 kg...20 kg (600 kg)	20-100 kpl	kaikki	CT 4-6	hyvä	helppo
Tarkkuusvalu	teräksinen tai Sn-Bi-seosmuotti, 3	1 g...1 kg	>500 kpl	Erikoisteräkset Cu-, Al - ja superseokset	CT 4-6	erittäin hyvä	kohtalaisen helppo

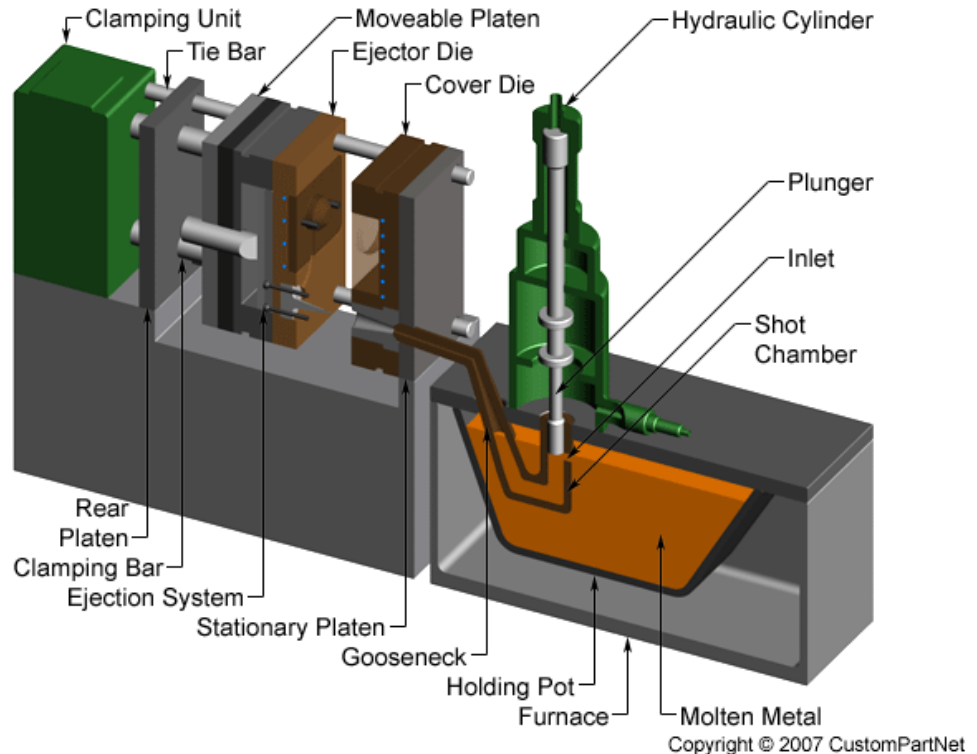


Molding methods, lost moulds	Tooling/pattern costs (1=inexpensive, 5=expensive)	Weight of the casting	Serial length	Cast metal	Tolerances	Design freedom	Structural change of tools
Hand moulding	Wood, plastic, 1	10 g - 100 tn	Single, short series	All	CT10-15	Good	Easy
Lost foam moulding	Polystyrene, 1	10 kg - 100 tn	Single, short series	All	CT11-14	Excellent	Very easy
Mechanical moulding	Plastic, metal, 3	1 kg - 1000 kg	> 50 pieces	All	CT7-10	Good	Easy, metal patterns expensive
Shell moulding	Metal, 4	100 g - 50 kg	> 100 pieces	All	CT7-10	Very good	Expensive
Investment casting	Metal, 3	1 g - 10 kg	> 500 pieces	Steels, Al, Cu, superalloys	CT4-6	Very good	Quite easy
Shaw-/Unicast moulding	Wood, plastic, 2	0,5 kg - 20 kg	20 - 100 pieces	All	CT4-6	Good	Easy

Die casting (hot chamber)

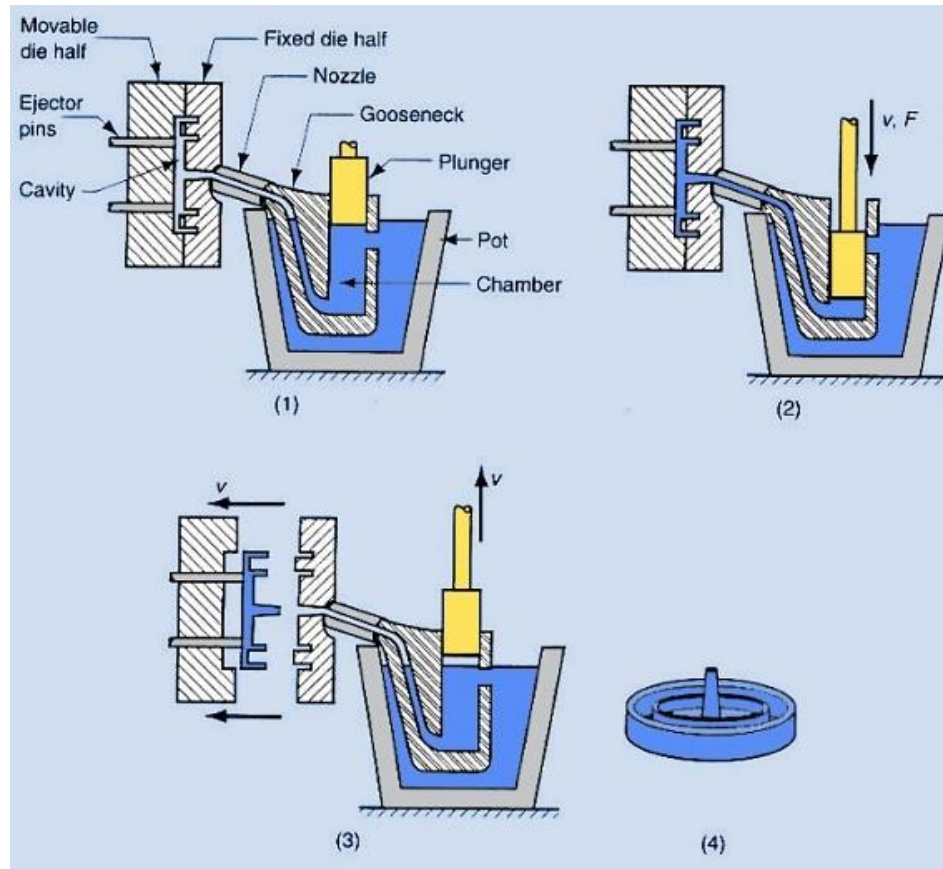
Permanent mould, no pattern

- **Alloys with low melting point**
 - Zn-, Sn-, Pb-alloys
- **Molten metal in a open pot**
- **Injection by plunger through a gooseneck**
- **70 – 350 bar/atm**
- **Fine grain due to pressure**
 - High strength
- **200-400 shots per hour**



Die casting (hot chamber)

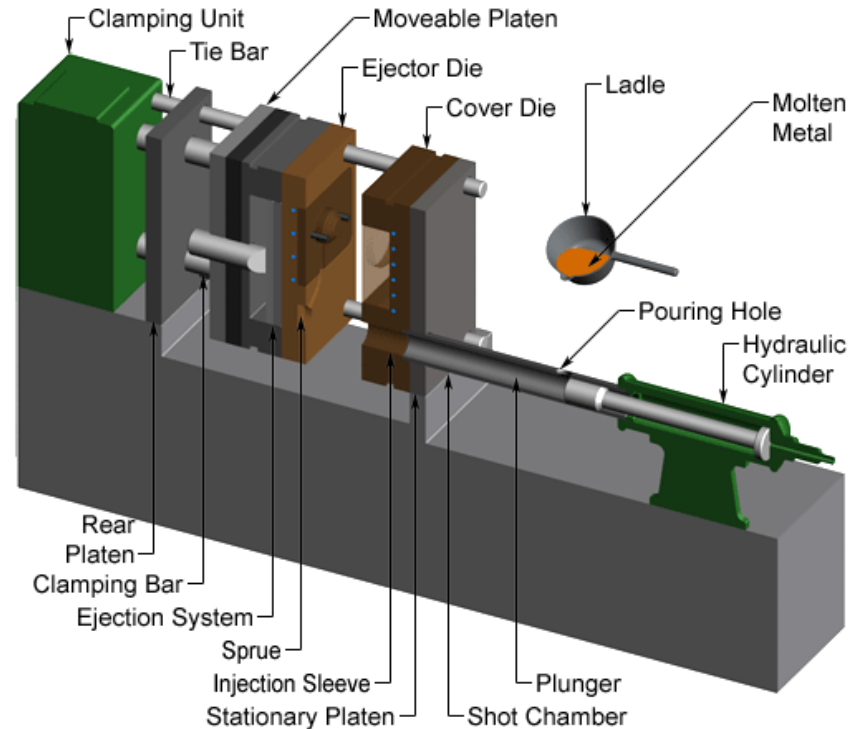
Permanent mould, no pattern



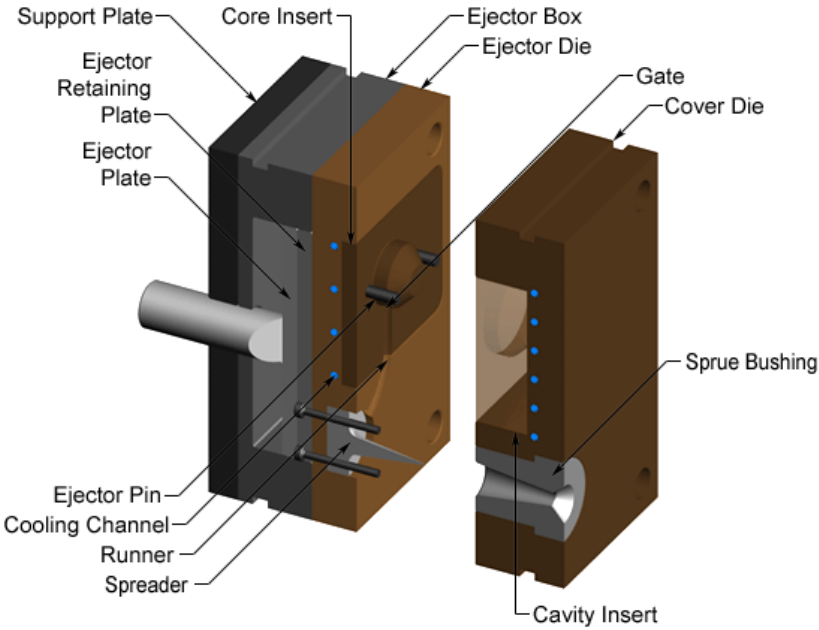
Die casting (cold chamber)

Permanent mould, no pattern

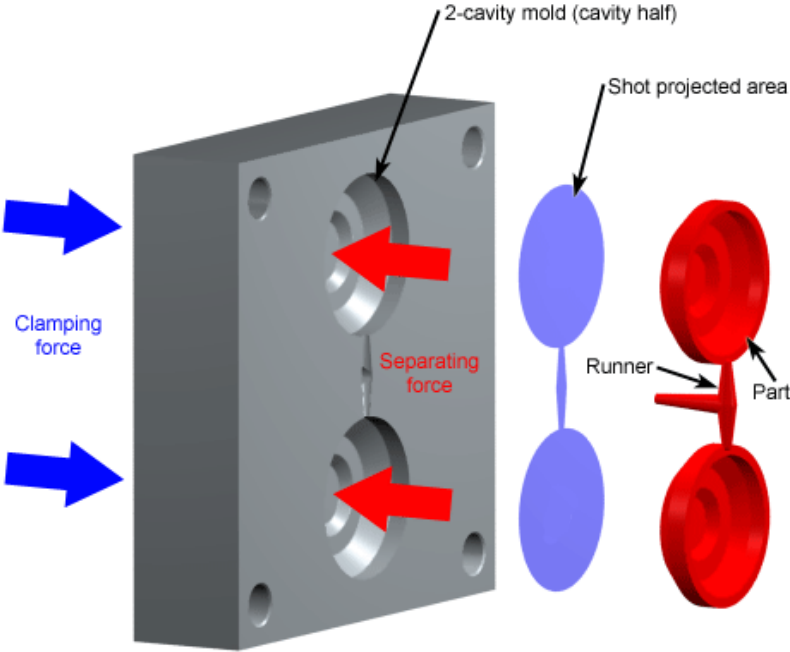
- **Alloys with higher melting point**
 - Al-, Cu-, Mg-alloys
- **Metal ladled into shot chamber**
- **Injection by a plunger**
- **140 – 1400 bar/atm**
- **Fine grain due to the pressure**
 - High strength
- **200-400 shots per hour**



Die casting



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Die casting

Advantages

- Large parts
- Complex shapes
- High strength parts
- Very good surface finish and accuracy
- High production rate
- Low labor cost
- Scrap can be recycled

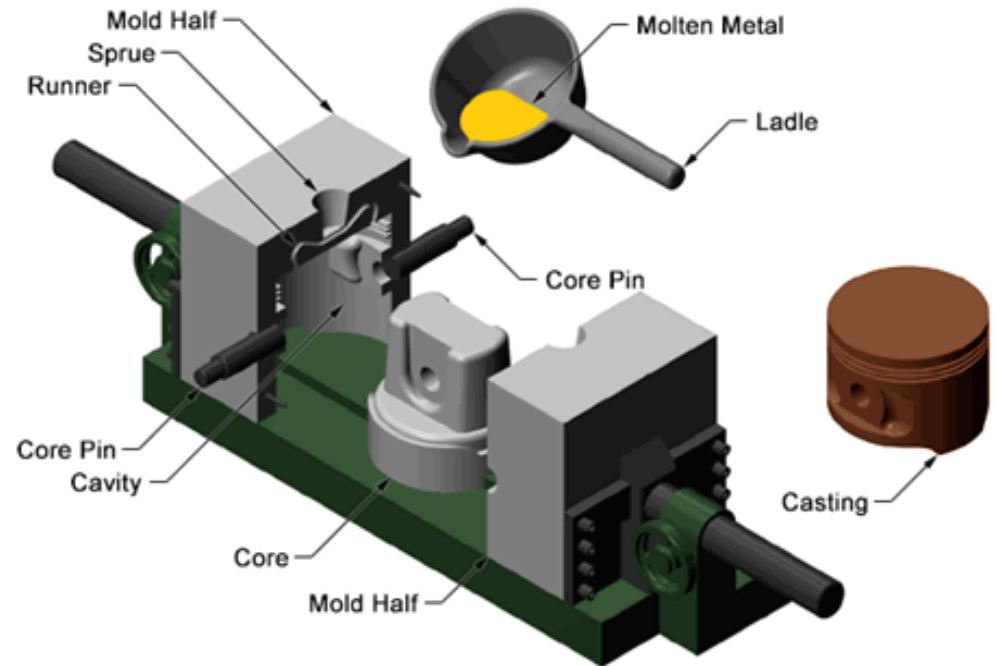
Disadvantages

- Trimming is required
- High tooling cost
- High equipment cost
- Limited die life
- Long lead time

Gravity die casting

Permanent mould, no pattern

- **Similar to sand casting and die casting**
- **Pre-heated permanent mould**
 - 150-260 °C
- **Ceramic coating (mould release) for part removal and mould lifetime**
- **Pouring like sand casting**



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Gravity die casting

Advantages

- Complex shapes
- Good mechanical properties
- Many material options
- Low porosity
- Low labor cost
- Scrap can be recycled

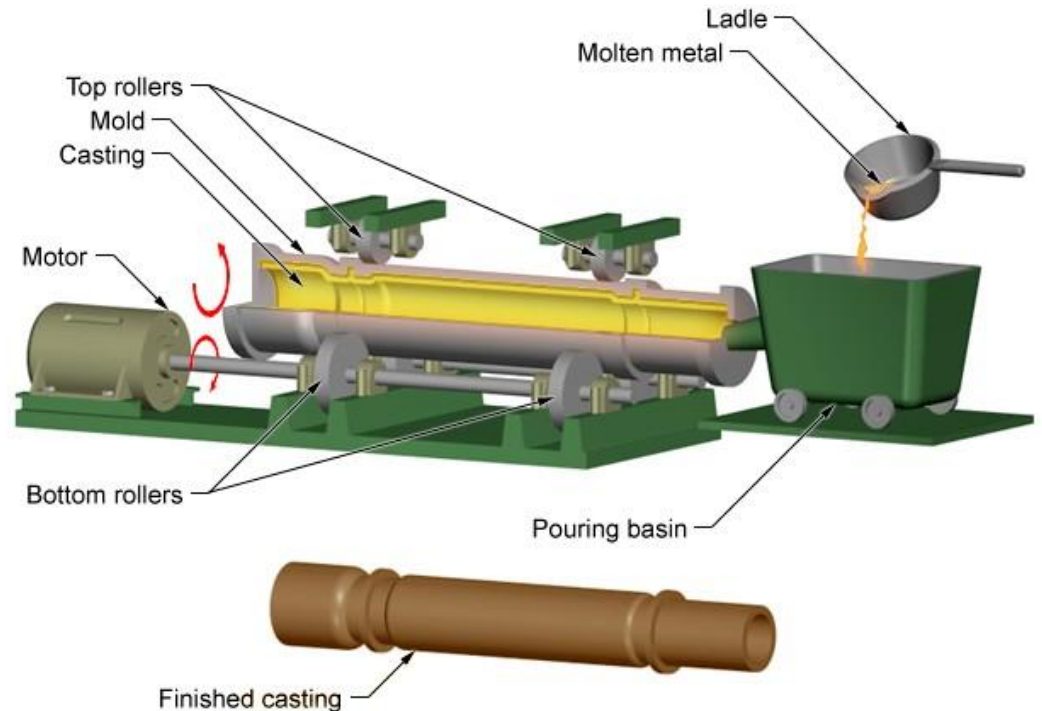
Disadvantages

- High tooling cost
- Long lead time possible

Centrifugal casting

Permanent mould, no pattern

- **Refractory ceramic coating**
- **No runner or gating system**
- **300-3000 RPM**
 - Fine grain at the outer surface
 - Less dense impurities at the inner surface



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Centrifugal casting

Advantages

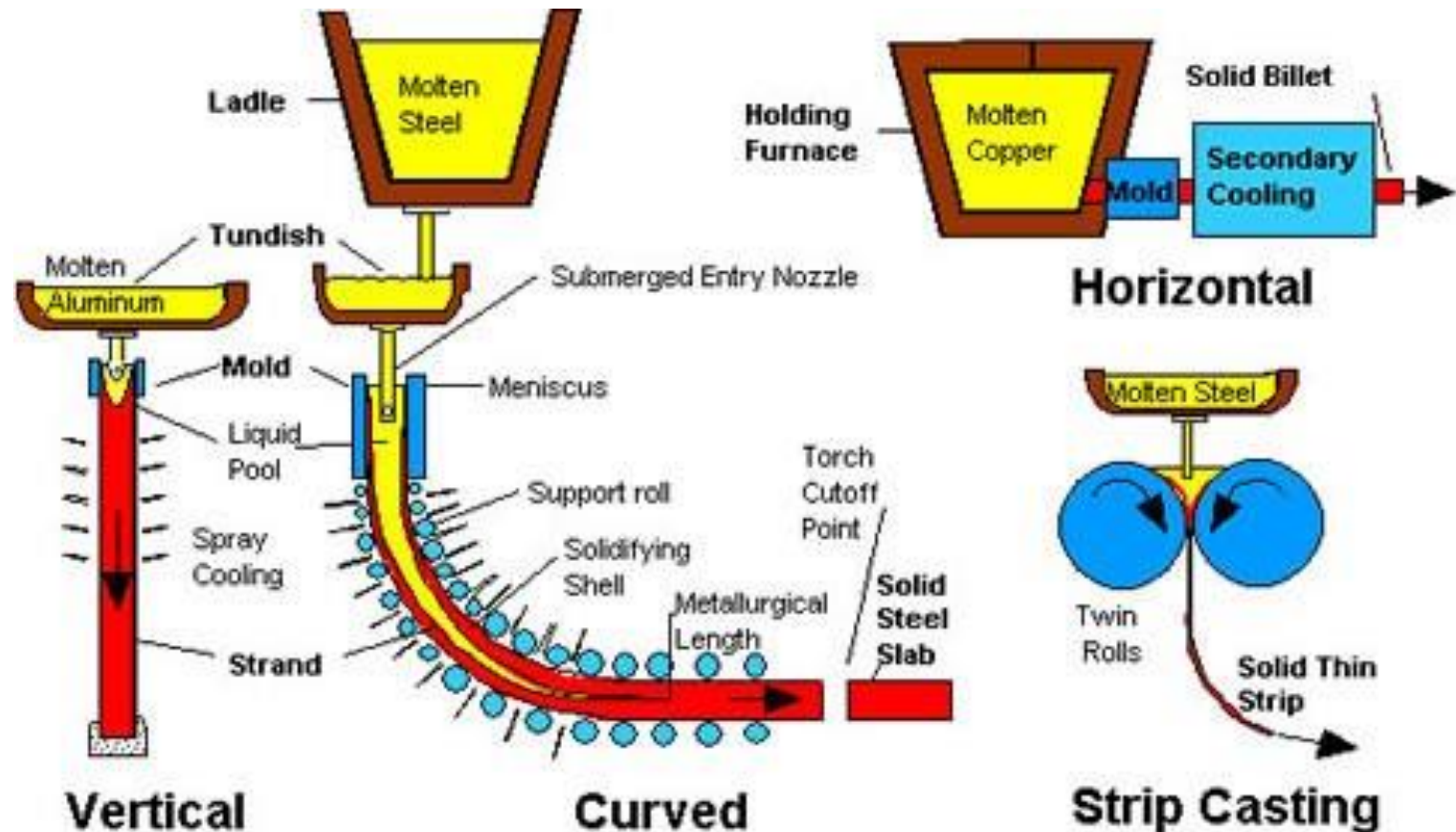
- Very large parts
- Good mechanical properties
- Good surface finish and accuracy
- Low equipment cost
- Low labor cost
- Little scrap generated

Disadvantages

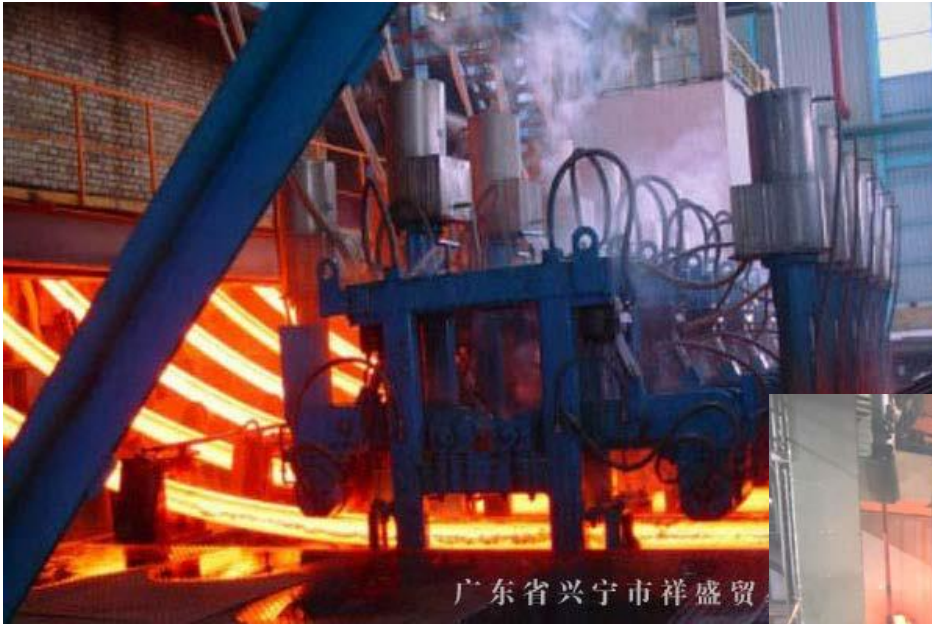
- Limited to cylindrical parts
- Secondary machining is often required for inner diameter
- Long lead time possible

Continuous casting/Strip casting

Permanent mould, no pattern



Continuous casting



Kaavausmenetelmä	Malli-/kestomuottivarusteet ja kustannukset	Valukappaleen koko tai paino	Sarjasuuruus	Valumetallit	Toleranssit	Muotoilun vapaus	Mallien/kestomuottien rakennemuutos
Kokillivalu	valurauta tai teräs 3	10 g...100 kg	sarjat, min 500-1000 kpl	Messingit, Al-, Mg-, Zn-, Sn- ja Pb-seokset, Fe-metallit rajoitetusti	CT 6-9	rajoitettu	kohtalaisen helppo
Painevalu	seostettua terästä 5	10 g...50 kg	sarjat, min. 1000-3000 kpl	Al-, Mg-, Zn- ja Cu-seokset	CT 4-8	erittäin hyvä	kallis
Keskipakovalu	valurauta, teräs tai keernamateriaalia, 3	putket, renkaat ϕ 50-1000 mm, muut 50 g...10 kg	sarjat	kaikki	CT 7-9	rajoitettu	kallis
Jatkuvavalu	metalli, grafiitti, vesijähdytys, 3	profilit ϕ 10-500 mm, rajaton pituus	sarjat	kaikki	poikkileikk. toleranssi 0,5%	rajoitettu	kallis



Molding methods, permanent mould	Tooling/mould or die costs (1=inexpensive, 5=expensive)	Weight of the casting	Serial length	Cast metal	Tolerances	Design freedom	Structural change of tools
Gravity die casting	Cast iron or steel, 3	10 g - 100 kg	500 - 1000 pieces	Nonferritic, Fe-based only limited	CT6-9	Good	Quite easy
Die casting	Tool steel, 5	10 g - 50 kg	> 5000 pieces	Nonferritic	CT4-8	Good	Expensive
Centrifugal casting	Cast iron or steel, 3	pipes, rings, diameter 50 - 1000 mm	Series	All	CT7-9	Restricted	Expensive
Continuous casting	Metal, graphite, water cooling, 4	Profiles, diameter 10 - 500 mm	Series	All		Restricted	Expensive

...and?

Casting is one of the *most versatile* production approaches for *complex geometries...*

... but the best methods vary for different *materials, batch sizes, part geometries, surface qualities, cost requirements and many other factors.*

Casting in general allows lots of design possibilities, **but is not without limitations...**

... but new processing techniques like **additive manufacturing** might get rid of some.