



 Department of Materials Science and Engineering 

Casting, Powder Metallurgy

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Materials Engineering
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 Outline 


- Solidification of metals
- Fluid flow, effect of cooling rate
- Cast defects
- Metal casting processes
 - Sand mold casting
 - Shell-mold casting
 - Investment casting
 - Evaporative-pattern casting
 - Permanent mold casting
 - Pressure die casting
 - Centrifugal casting

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 History 

- B.C. 3000-1500 Bronze age (tin-bronze)
- B.C. 224 Colossus of Rhodes (32 m high, bronze)
- 1252 Great Buddha, Japan(120 t (9% Sn, 20% Pb))
- 1400 Yongle Great Bell (China, Beijing) 46 t, 120 dB-20 km)
- 1586 Tsar cannon
- 1709 Cast iron bridge (USA Coalbrookdale)
- 1735 Tsar Bell (193 t)



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att Casting process MŰEGYETEM 1792

The casting process basically involves:

- pouring molten metal into the mold cavity
- solidification and cooling of the metal in the mold
- removing the part from the mold

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att Efficiency and energy consumption MŰEGYETEM 1792

| Utilization of the mat. | Process | Energy consumption |
|-------------------------|-----------------------|--------------------|
| 90 | Casting | 0-38 |
| 95 | Powder metallurgy | 29 |
| 85 | Cold and warm forming | 41 |
| 75-80 | Closed die forging | 41-49 |
| 45-40 | Machining | 66-82 |

(1kg product)

100% ← 0% 0 MJ ⇒ 100 MJ

<https://www.machinedesign.com/materials/metals/article/21834820/reap-the-benefits-of-modern-materials>

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att Solidification of pure metals and eutectic alloys MŰEGYETEM 1792

Latent heat
Solidification takes place at a constant temperature

Pure metals and eutectic alloys - good castability

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Shrinkage

Risers (feeders):
reservoirs of molten metal prevent porosity due to shrinkage

Labels: Pouring cup, Side riser, Top riser, Sprue, Well, Runner, Gate, Casting, mold cavity

Gating system (sprue, runners, gates) sand casting: traps contaminants

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Sand casting

Minimize turbulence and formation of air bubbles.

The controlled entrances from the runners into the mold cavities.

Slow down and smooth out the flow (uniform).

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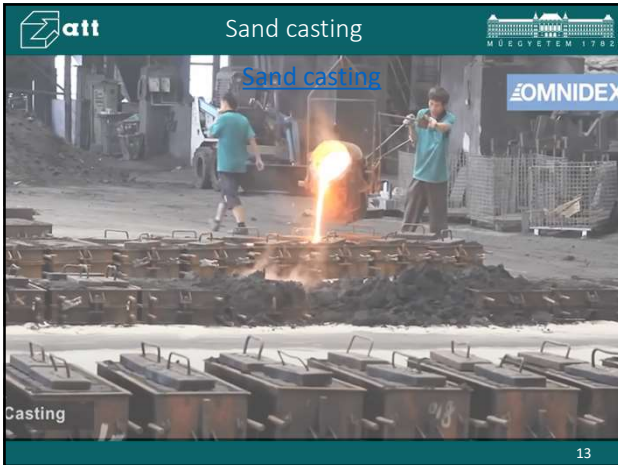
Sand casting

Molding sands + Binders

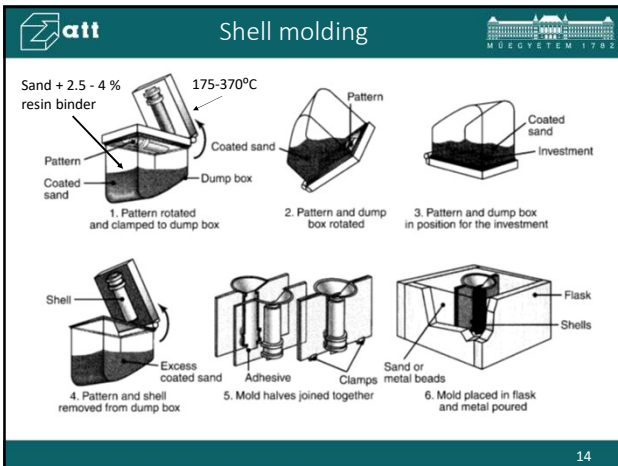
- Refractoriness
- Chemical inertness
- Permeability (to exhaust gases)
- Surface finish
- Cohesiveness
- Flowability
- Collapsibility
- Availability/cost

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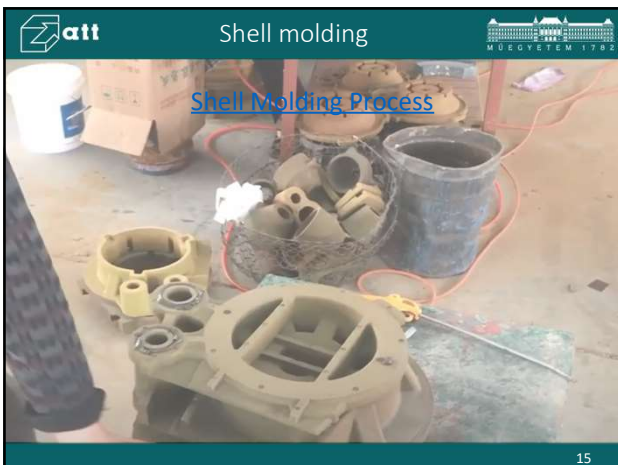
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att Evaporative-pattern casting (Lost-foam Process)

1. Pattern molding 2. Cluster assembly 3. Coating

4. Compacted in sand 5. Casting 6. Shakeout

polystyrene pattern

Coating with water-based refractory slurry & drying

polystyrene pattern evaporates upon contact with molten metal

The degradation products from the polystyrene are vented into the surrounding sand.

Cluster Parts

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att Investment (precision) casting

1. Injecting wax or plastic pattern 2. Ejecting pattern 3. Pattern assembly (Tree)

4. Slurry coating 5. Stucco coating

6. Completed mold 7. Pattern melt-out 8. Pouring 9. Shakeout 10. Pattern

wax can be recovered and reused

Molten metal

Molten wax or plastic

Heat

Casting

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att Investment (precision) casting

Advantages

- Excellent surface finish
- High dimensional accuracy
- Intricate parts are castable
- Almost any metal can be cast
- No flash or parting lines

Disadvantages

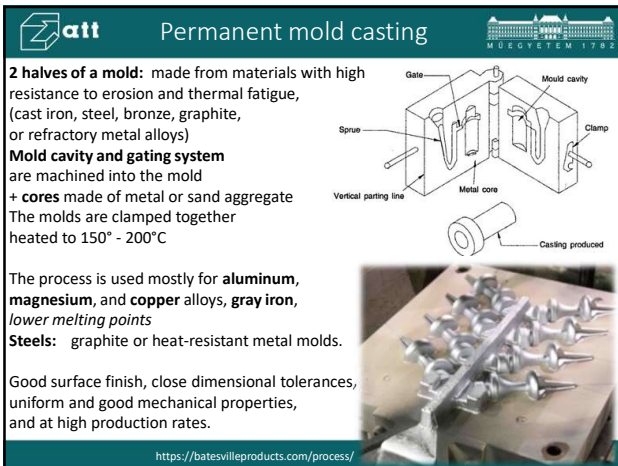
- It can be difficult to cast objects requiring cores.
- This process is expensive, is usually limited to small casting, and presents some difficulties where cores are involved.
- Holes cannot be smaller than 1/16 in. (1.6 mm) and should be no deeper than about 1.5 times the diameter.
- Investment castings require longer production cycles compared to other casting processes.

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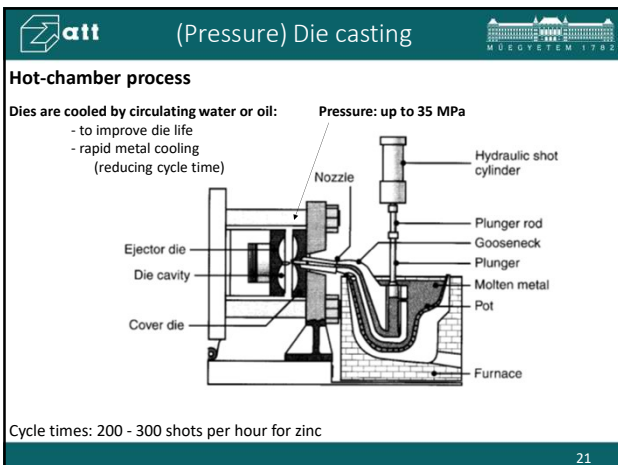
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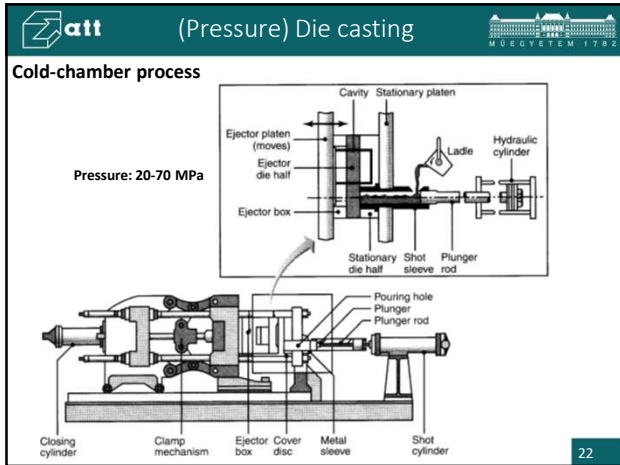
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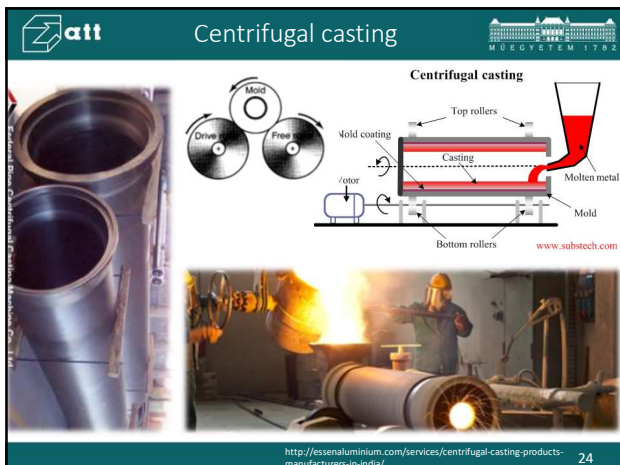
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att Metal casting processes overview M Ű E G Y E T E M 1 7 9 2

| | Sand | Shell | Evaporative pattern | Plaster | Investment | Permanent mold | Die | Centrifugal |
|-------------------------|------------|--------|---------------------|---------------|------------|----------------|----------------|-------------|
| material | | All | | Non-ferrous | All | | Non-ferrous | All |
| Weight | | | | | | | | |
| Min | 0.01 | 0.01 | 0.01 | 0.01 | 0.001 | 0.1 | <0.01 | 0.01 |
| Max | No limit | 100+ | 100+ | 50+ | 100+ | 300 | 50 | 5000+ |
| Surface | acceptable | good | acceptable | good | Very good | good | good | good |
| Shape complexity | good | good | good | good | Very good | good | Very good | good |
| Dim. tolerance | 1.6-4 mm | +0.003 | | +0.005 - 0.01 | +0.005 | ±0.015 | +0.001 - 0.005 | 0.015 |
| Min. thickness | 3 | 2 | 2 | 1 | 1 | 2 | 0.5 | 2 |
| Min. quantity | 1 | 100 | 500 | 10 | 10 | 1000 | 10 000 | 10-10 000 |

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att Metal casting processes M Ű E G Y E T E M 1 7 9 2

| Process / mass (kg) | 0.01 | 0.1 | 1 | 10 | 100 | 1000 | 10 000 | 100 000 |
|---------------------|------|-----------------|---|----|-----|------|--------|---------|
| Sand | | Ra =100 µm | | | | | | |
| Shell | | Ra =10-25 µm | | | | | | |
| Investment | | Ra < 10 µm | | | | | | |
| Permanent mold | | Ra = 10-50 µm | | | | | | |
| Die | | Ra =1.6 - 10 µm | | | | | | |

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att Powder metallurgy MŰEGYETEM 1792

- Components are made of metal powders
- Reduce the need of metal removal
- Materials that cannot be melted or formed in other ways (WC)
- Very high alloying content (HSS)



<https://www.pm-review.com/introduction-to-powder-metallurgy/why-powder-metallurgy/>


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Steps

1. Powder blending
2. Die compaction
3. Sintering
 1. Coining
 2. Heat treatment



Processes

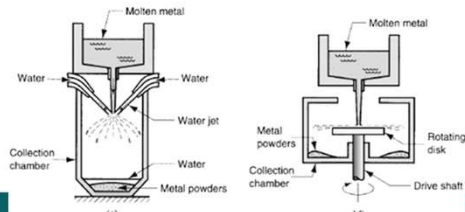
- Powder forging
Press and sinter + hot forging
- Hot isostatic pressing
Powder in sealed can, $0.7 T_{hom}$, 100 MPa
- Metal injection moulding
Powder + binder injection moulded (green), heated (brown) and sintered
- Electric current assisted sintering
Electric current to densify powders
- Additive manufacturing
SLS, SLM, EBM

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att Powder manufacturing MŰEGYETEM 1792

- Sponge iron process
 Fe_3O_4 ore is mixed with coke and lime and placed in a silicon carbide retort. The filled retort is then heated in a kiln, where the reduction process leaves an iron "cake" and a slag.
- Atomization
Forcing a molten metal stream through an orifice at moderate pressures. Gas, liquid is introduced or centrifugal process.



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att Powder compaction + Sintering

- Die pressing
Presses are used (hydraulic, mechanical, servo-electrical)
- Isostatic pressing
In hot isostatic pressing (HIP) compact formation and sintering occur simultaneously.
- Sintering
During this process, the surfaces of the particles are bonded and desirable properties are achieved.

U.S. powder metallurgy market size, by application, 2016 - 2027 (USD Billion)

| Year | Aerospace & Defense | Automotive | Medical & Dental | Oil & Gas | Industrial |
|------|---------------------|------------|------------------|-----------|------------|
| 2016 | 0.52 | | | | |
| 2017 | 0.60 | | | | |
| 2018 | | | | | |
| 2019 | | | | | |
| 2020 | | | | | |
| 2021 | | | | | |
| 2022 | | | | | |
| 2023 | | | | | |
| 2024 | | | | | |
| 2025 | | | | | |
| 2026 | | | | | |
| 2027 | | | | | |

<https://www.grandviewresearch.com/industry-analysis/powder-metallurgy-market>

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att Powder metallurgy

Powder Metallurgy

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Thank you for your attention!

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- <https://youtu.be/N4-kfSD6XJI>

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