

Casting, Powder Metallurgy

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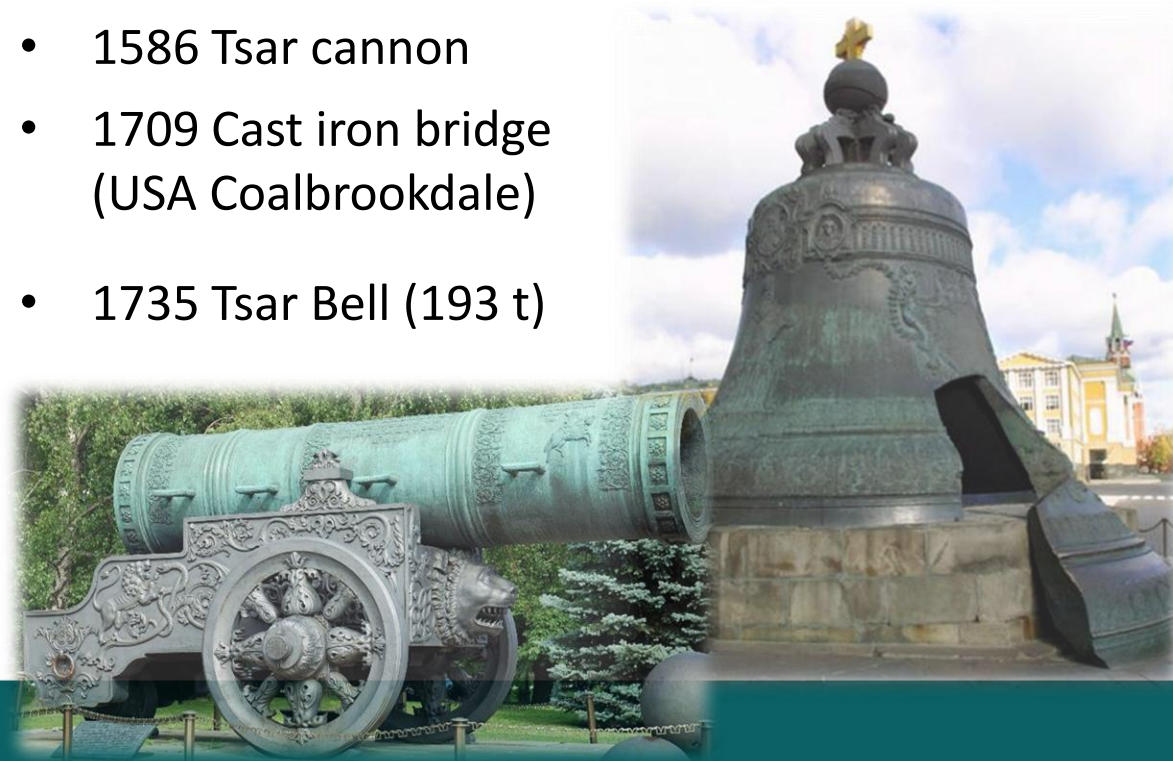
Materials Engineering

BMEGEMTBGF1

2025 Fall semester

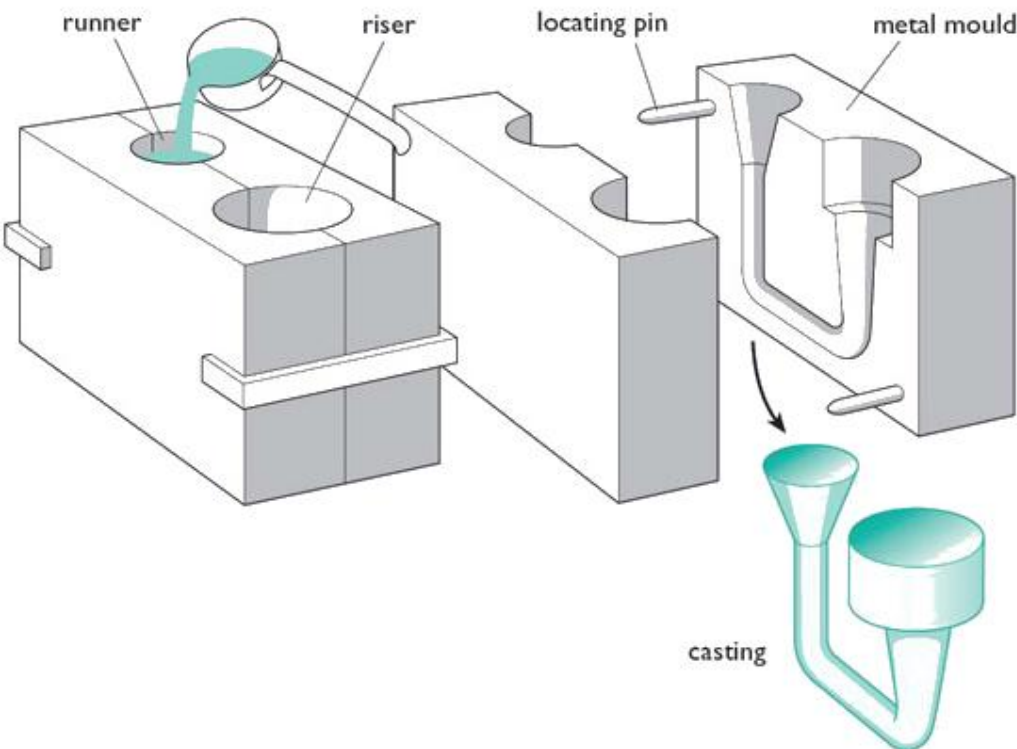
- Solidification of metals
- Fluid flow, effect of cooling rate
- Cast defects
- Metal casting processes
 - Sand mold casting
 - Shell-mold casting
 - Investment casting
 - Evaporative-pattern casting
 - Permanent mold casting
 - Pressure die casting
 - Centrifugal casting

- 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)



The casting process basically involves:

- (a) pouring molten metal into the mold cavity
- (b) solidification and cooling of the metal in the mold
- (c) removing the part from the mold

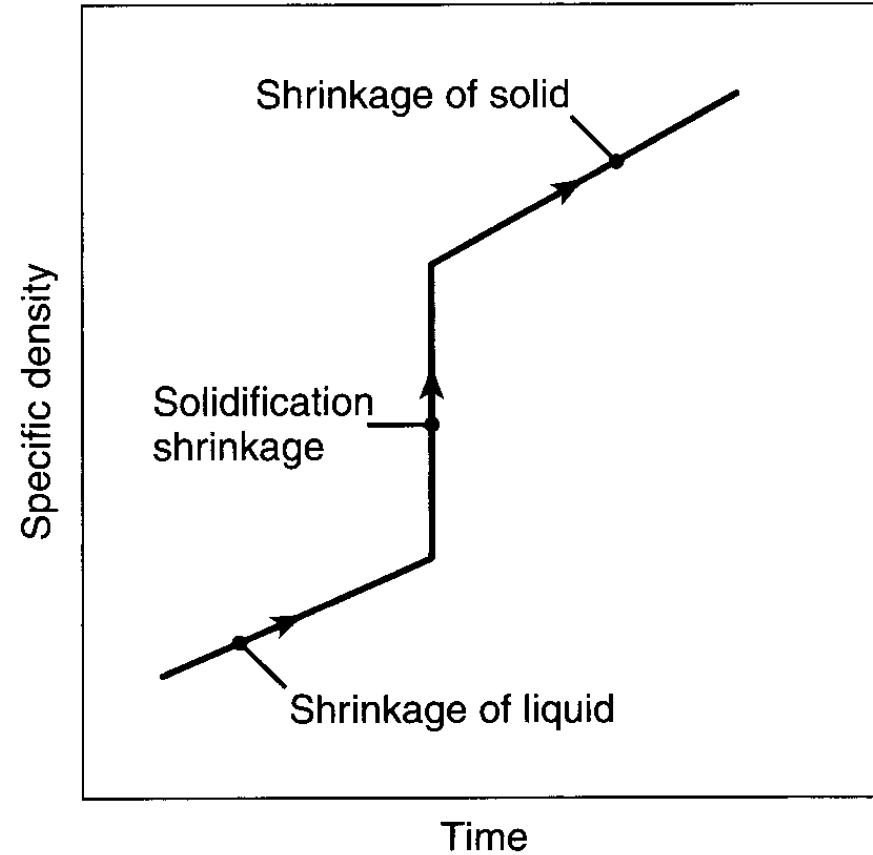
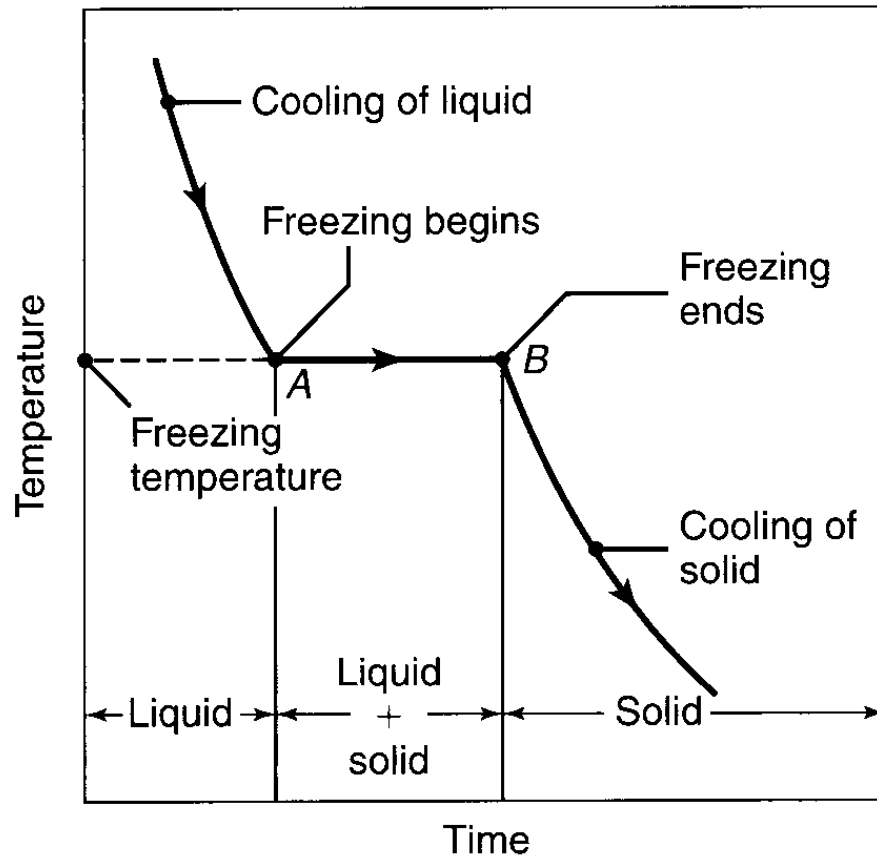


Utilization of the mat.		Process	Energy consumption	
90		Casting	0-38	(1kg product)
95		Powder metallurgy	29	
85		Cold and warm forming	41	
75-80		Closed die forging	41-49	
45-40		Machining	66-82	
100%	← 0%		0 MJ → 100 MJ	

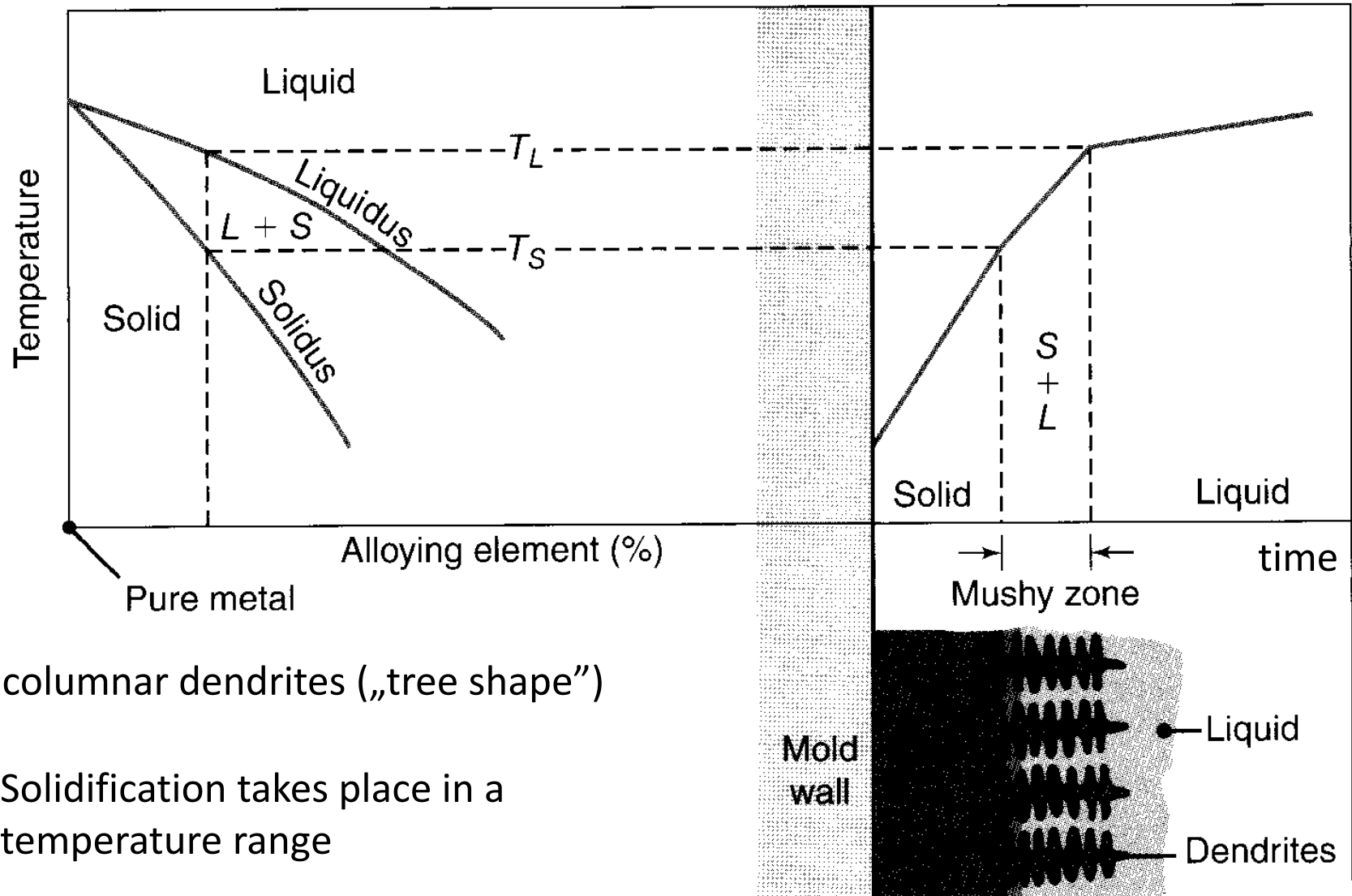


Latent heat

Solidification takes place at a constant temperature

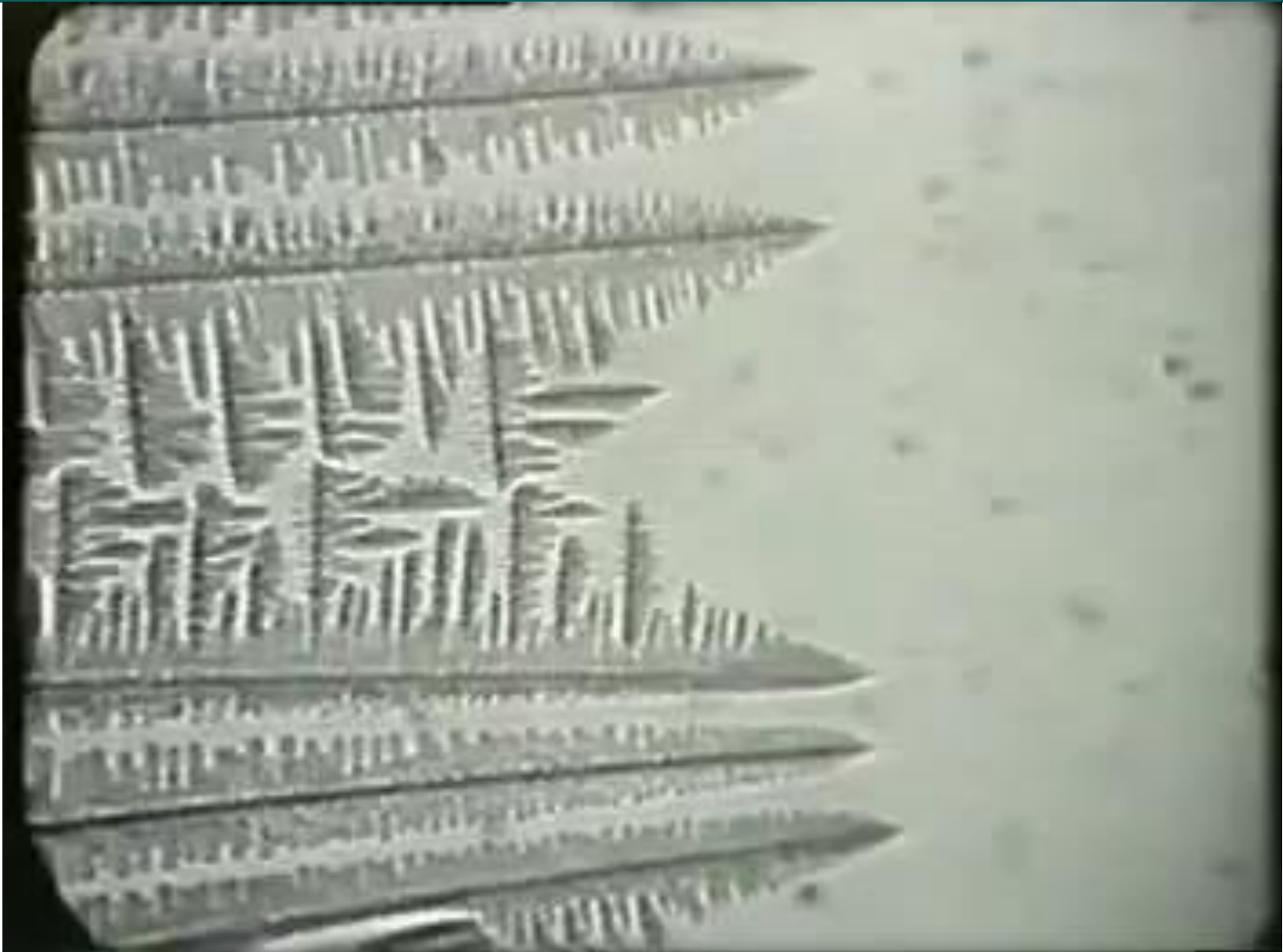


Pure metals and eutectic alloys - good castability



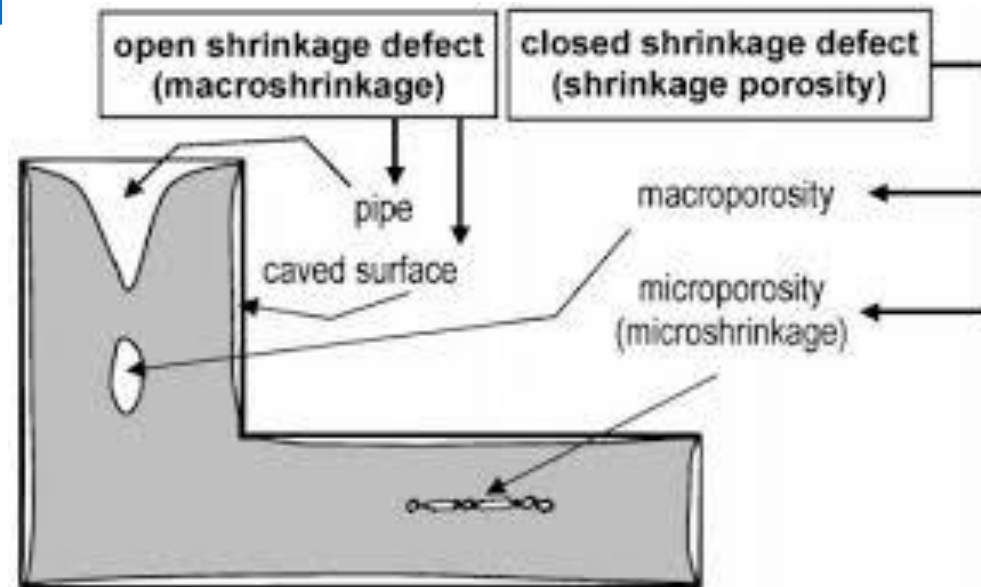
columnar dendrites („tree shape”)

Solidification takes place in a temperature range



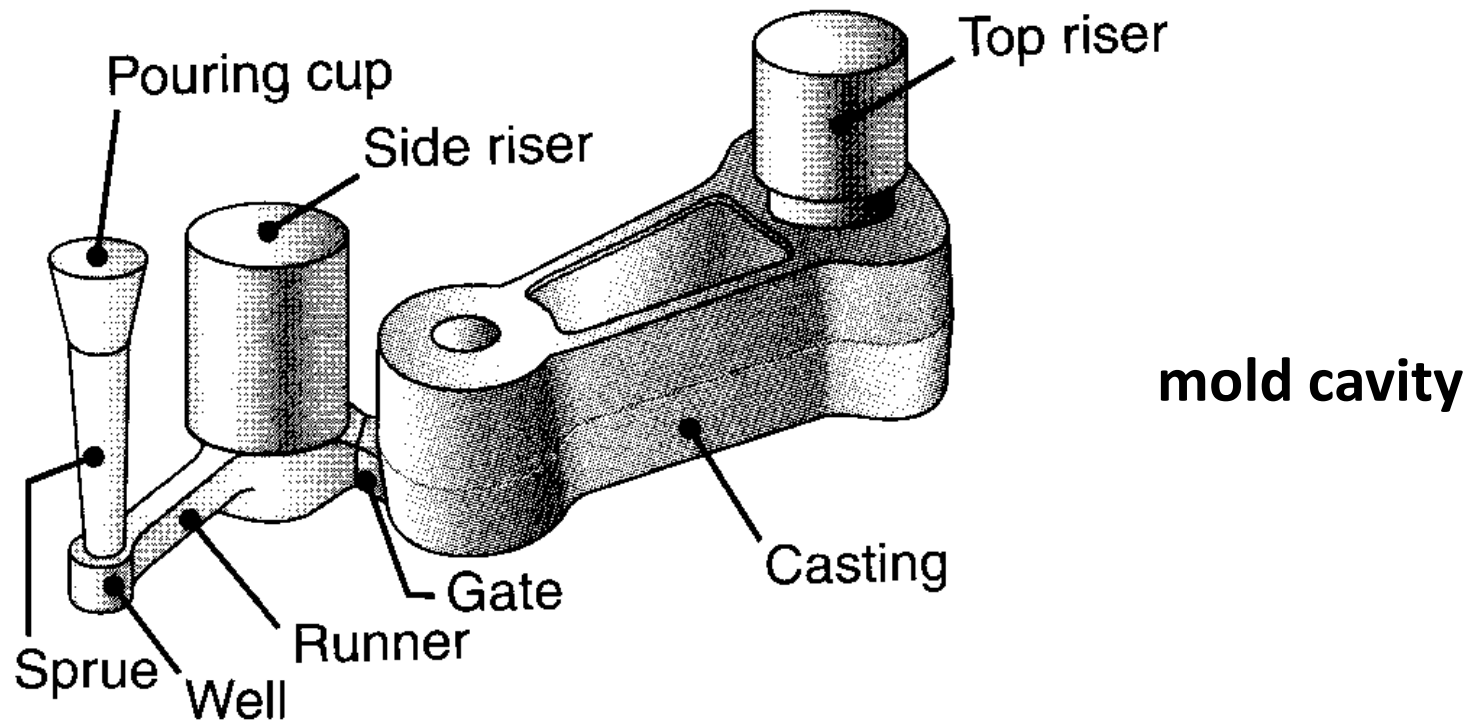
Volumetric Solidification Contraction or Expansion for Various Cast Metals

Contraction (%)		Expansion (%)	
Aluminum	7.1	Bismuth	3.3
Zinc	6.5	Silicon	2.9
Al-4.5% Cu	6.3	Gray iron	2.5
Gold	5.5		
White iron	4-5.5		
Copper	4.9		
Brass (70-30)	4.5		
Magnesium	4.2		
90% Cu-10% Al	4		
Carbon steels	2.5-4		
Al-12% Si	3.8		
Lead	3.2		

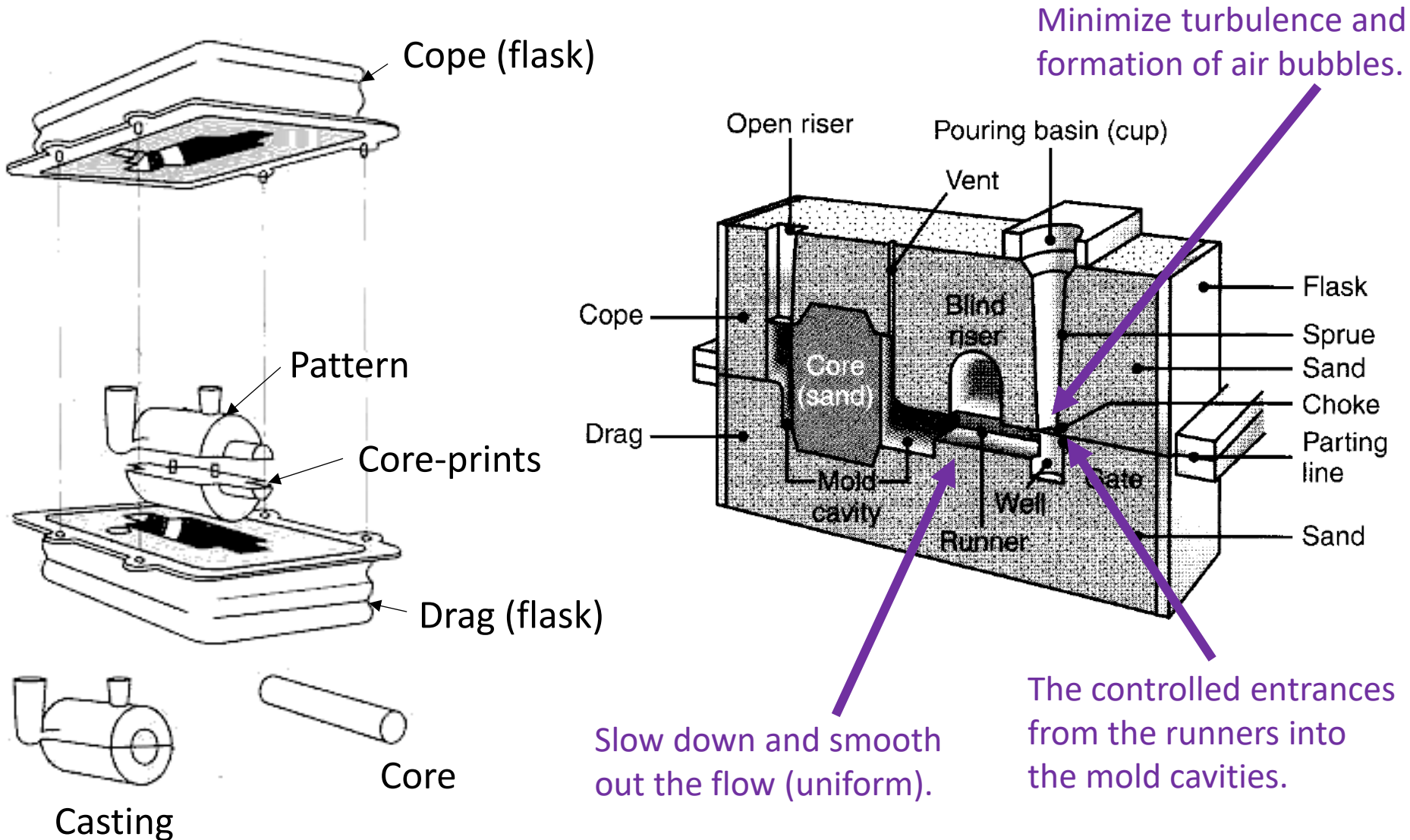


Risers (feeders):

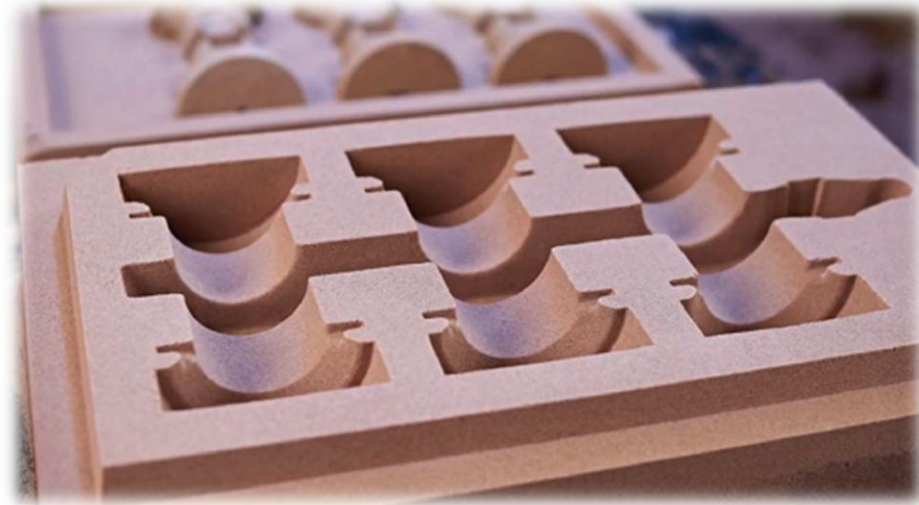
reservoirs of molten metal prevent porosity due to shrinkage



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



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



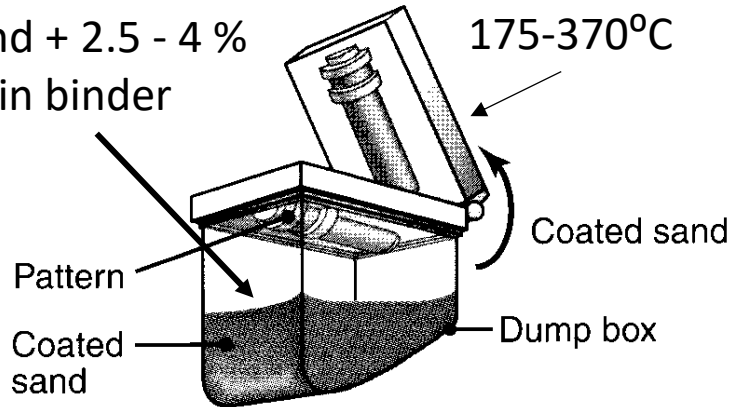
Sand casting

OMNIDEX

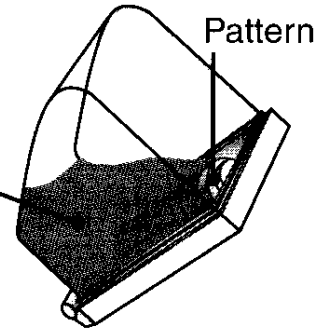


Sand + 2.5 - 4 %
resin binder

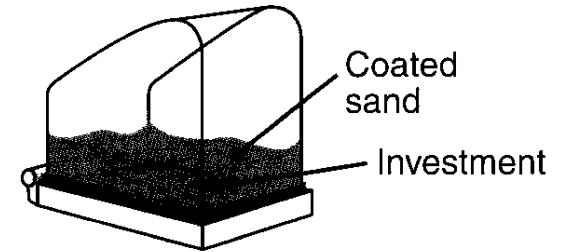
175-370°C



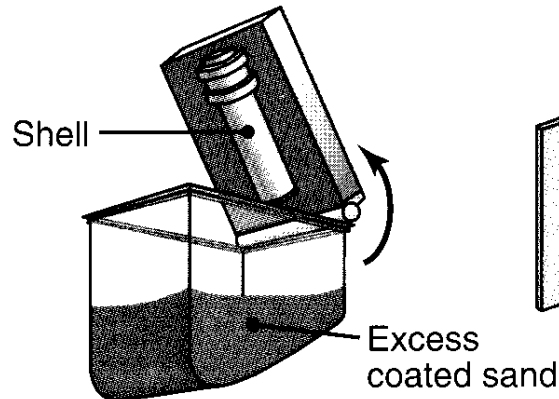
1. Pattern rotated
and clamped to dump box



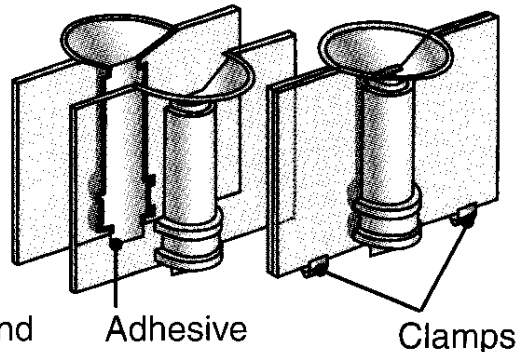
2. Pattern and dump box
rotated



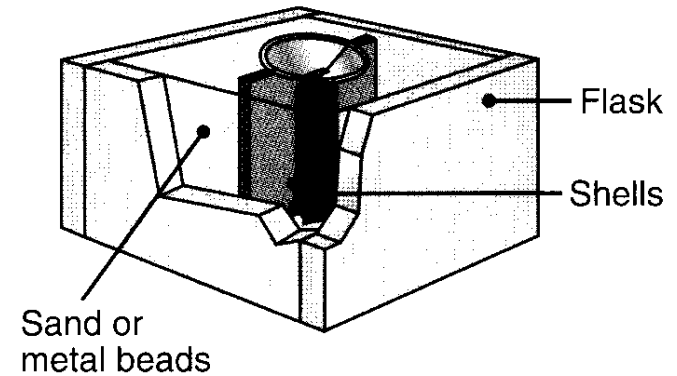
3. Pattern and dump box
in position for the investment



4. Pattern and shell
removed from dump box



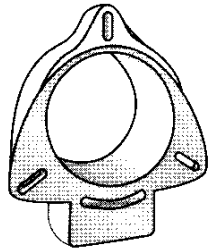
5. Mold halves joined together



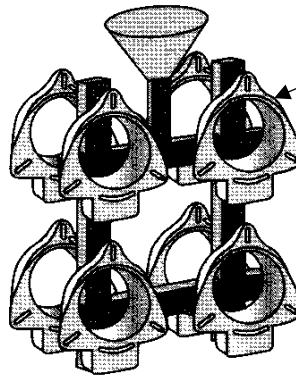
6. Mold placed in flask
and metal poured

Shell Molding Process



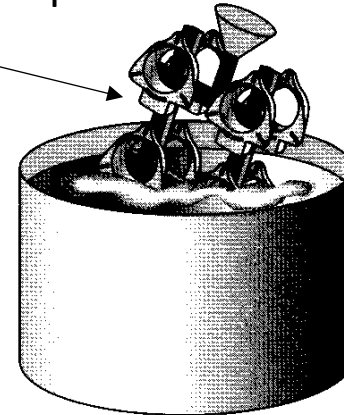


1. Pattern molding



2. Cluster assembly

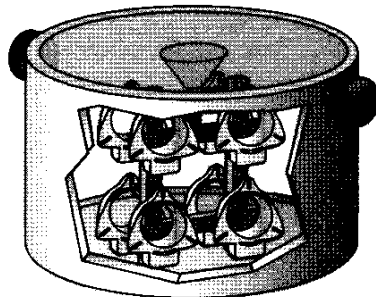
polystyrene pattern



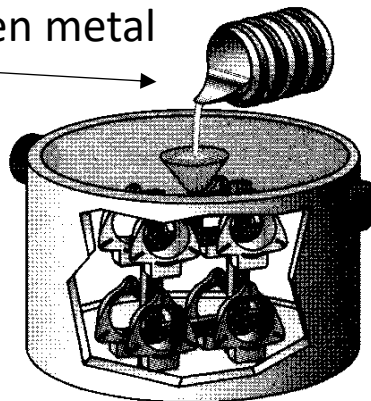
3. Coating

Coating with
water-based
refractory slurry
& drying

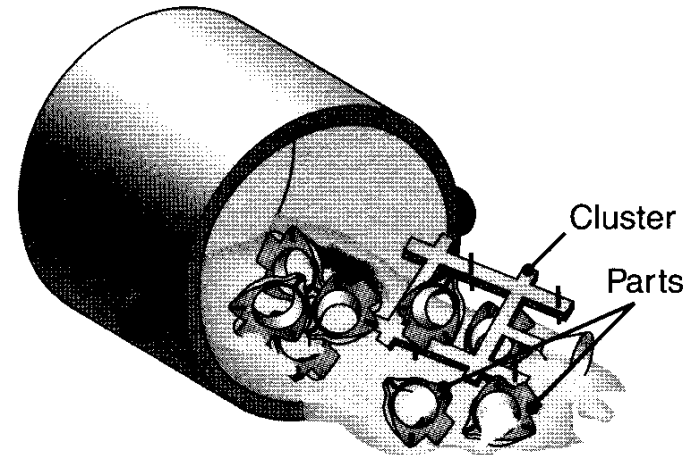
polystyrene pattern evaporates
upon contact with molten metal



4. Compacted in sand



5. Casting

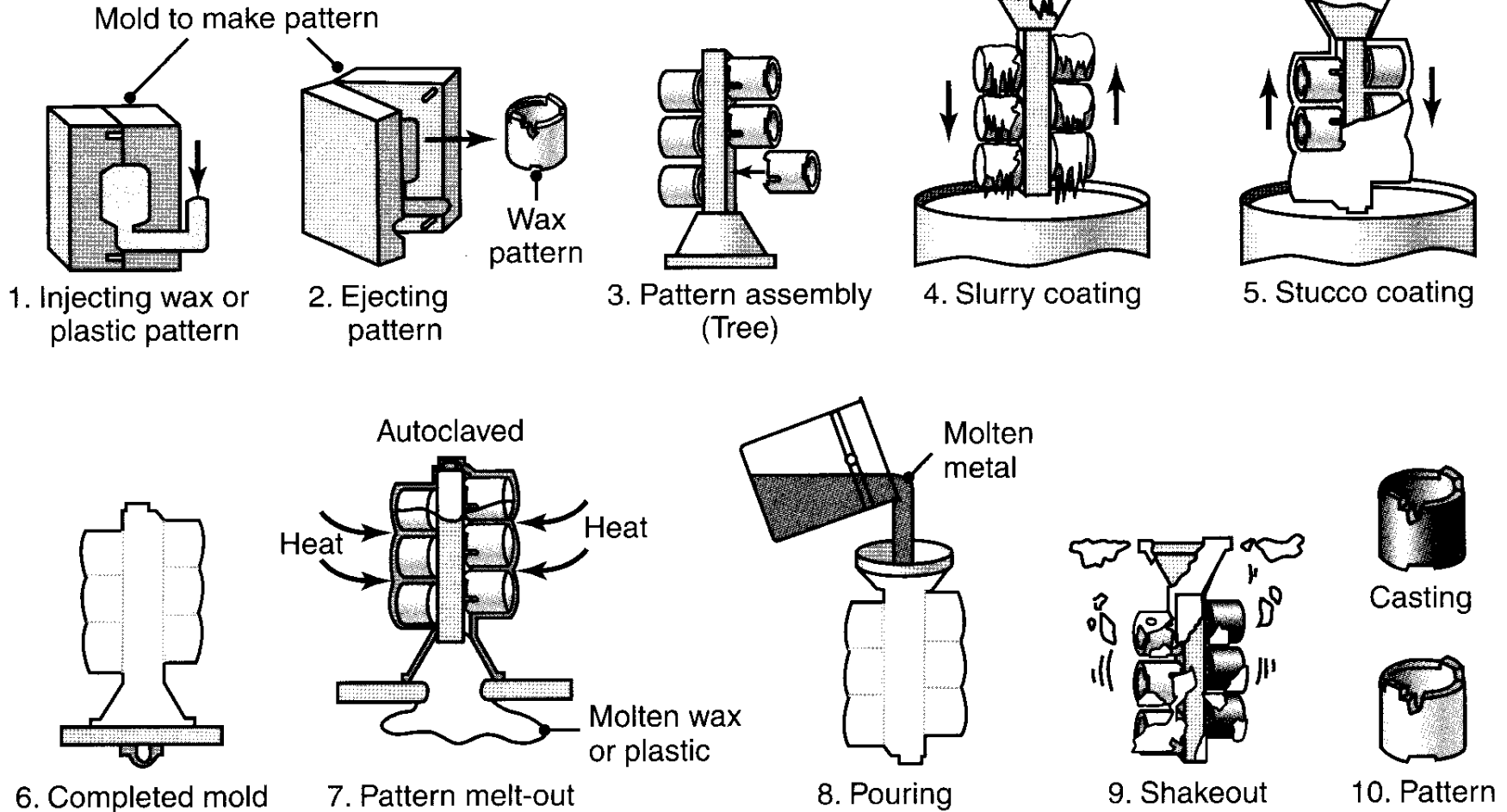


6. Shakeout

Cluster
Parts

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

wax can be recovered
and reused



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.

Investment Casting Process



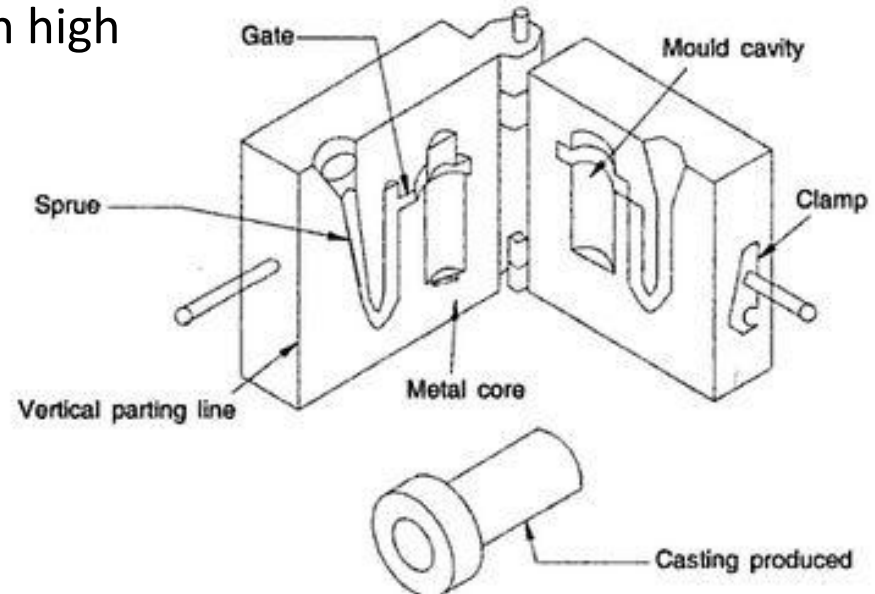
2 halves of a mold: made from materials with high resistance to erosion and thermal fatigue, (cast iron, steel, bronze, graphite, or refractory metal alloys)

Mold cavity and gating system

are machined into the mold

+ **cores** made of metal or sand aggregate

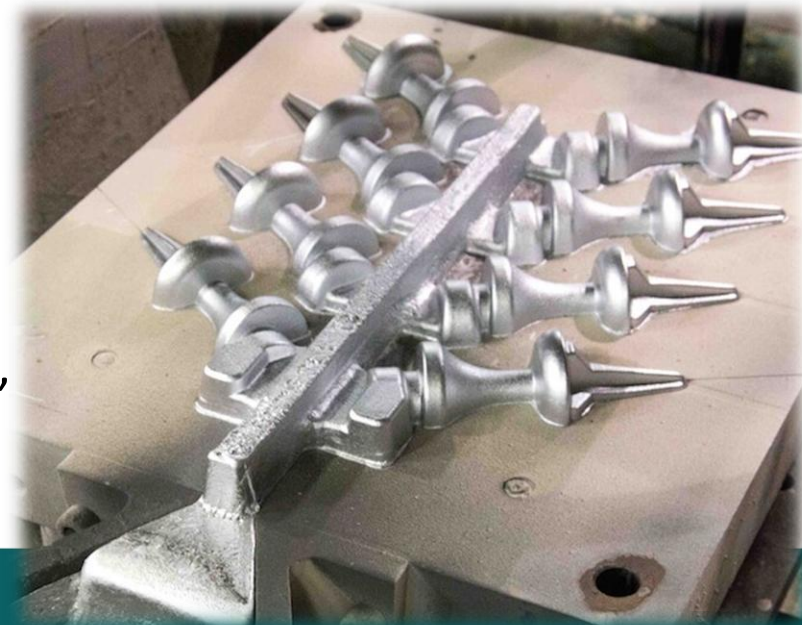
The molds are clamped together
heated to 150° - 200°C



The process is used mostly for **aluminum**, **magnesium**, and **copper** alloys, **gray iron**, *lower melting points*

Steels: graphite or heat-resistant metal molds.

Good surface finish, close dimensional tolerances, uniform and good mechanical properties, and at high production rates.

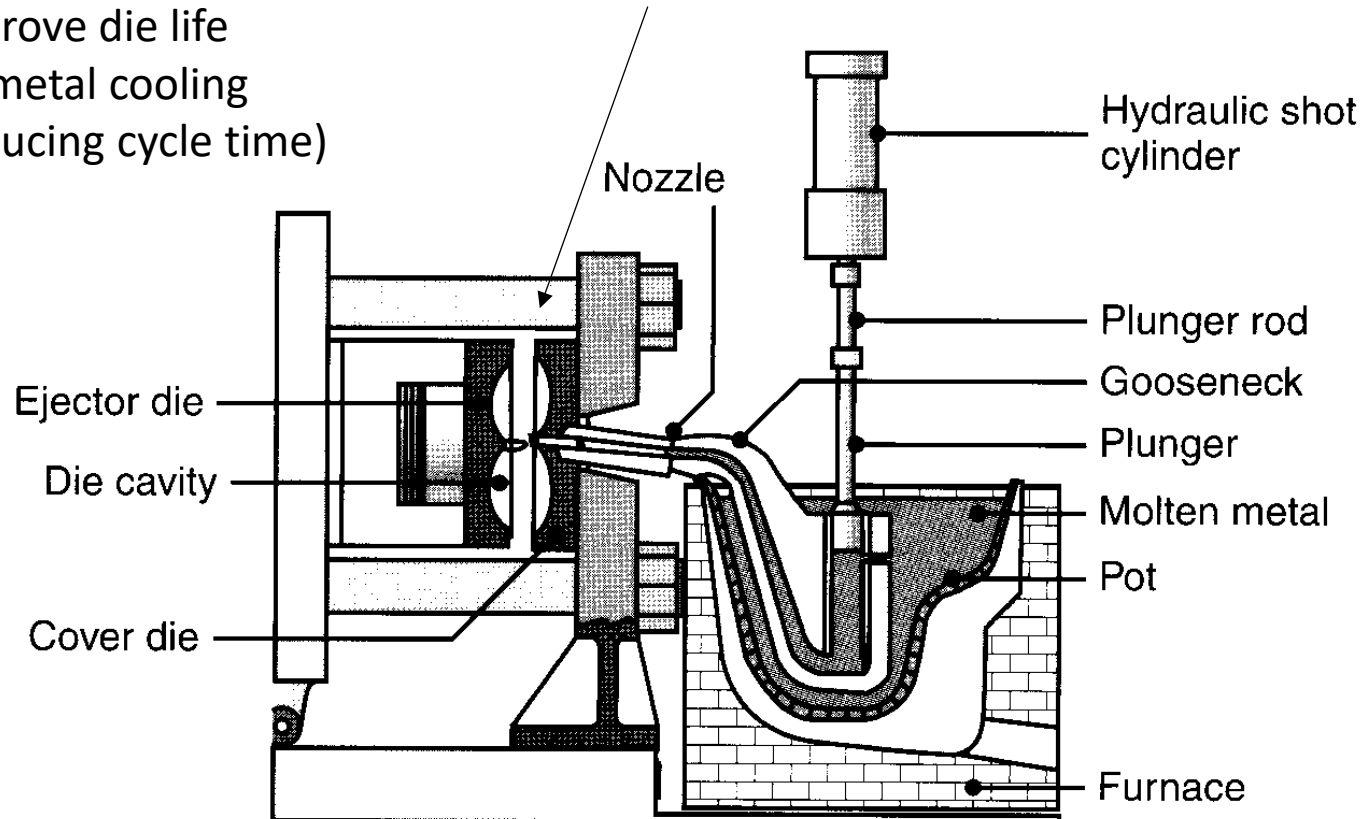


Hot-chamber process

Dies are cooled by circulating water or oil:

- to improve die life
- rapid metal cooling
(reducing cycle time)

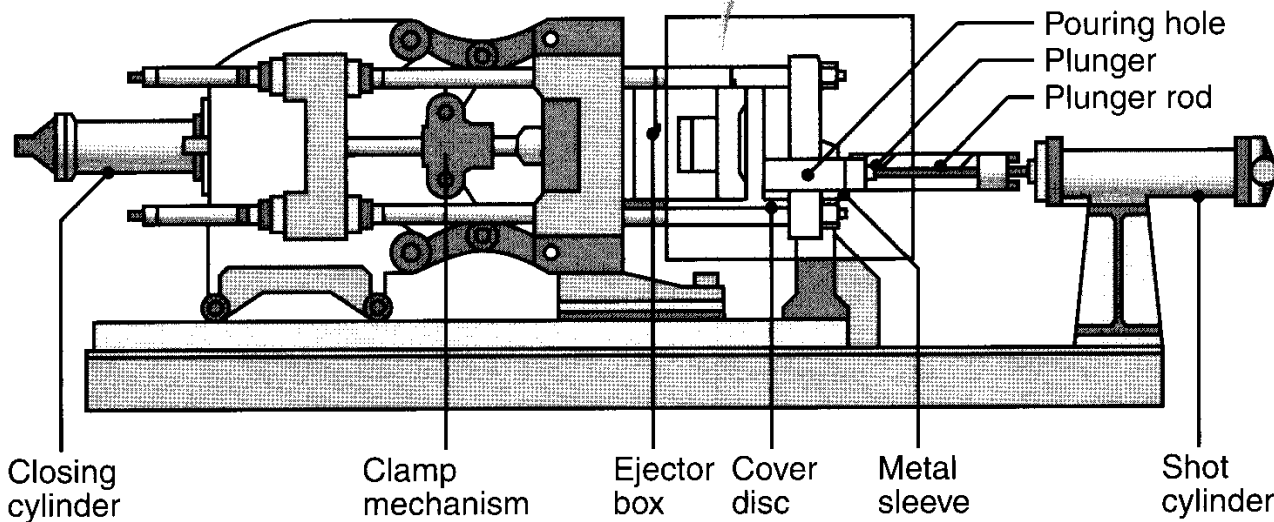
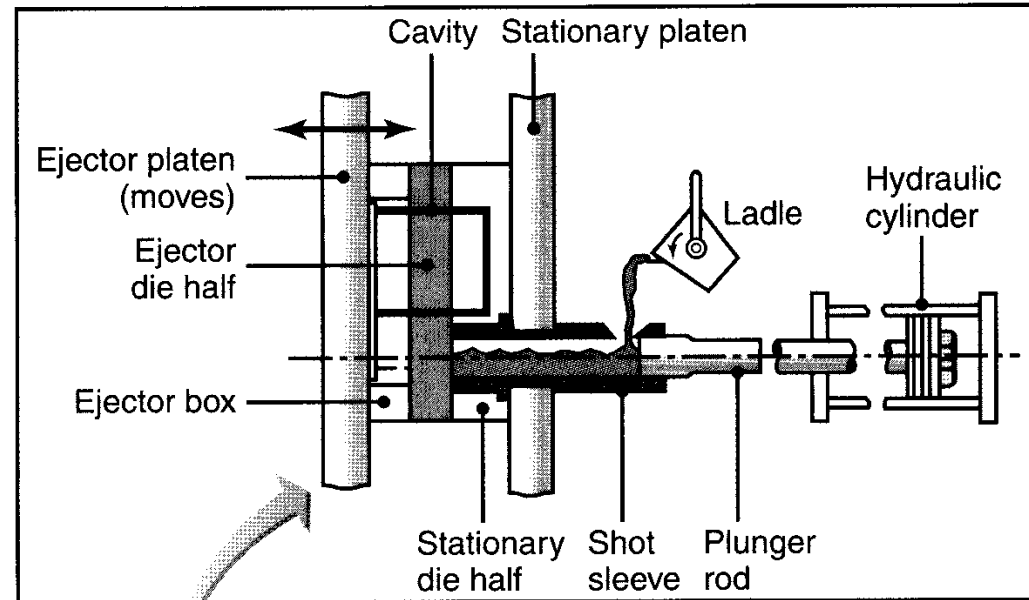
Pressure: up to 35 MPa



Cycle times: 200 - 300 shots per hour for zinc

Cold-chamber process

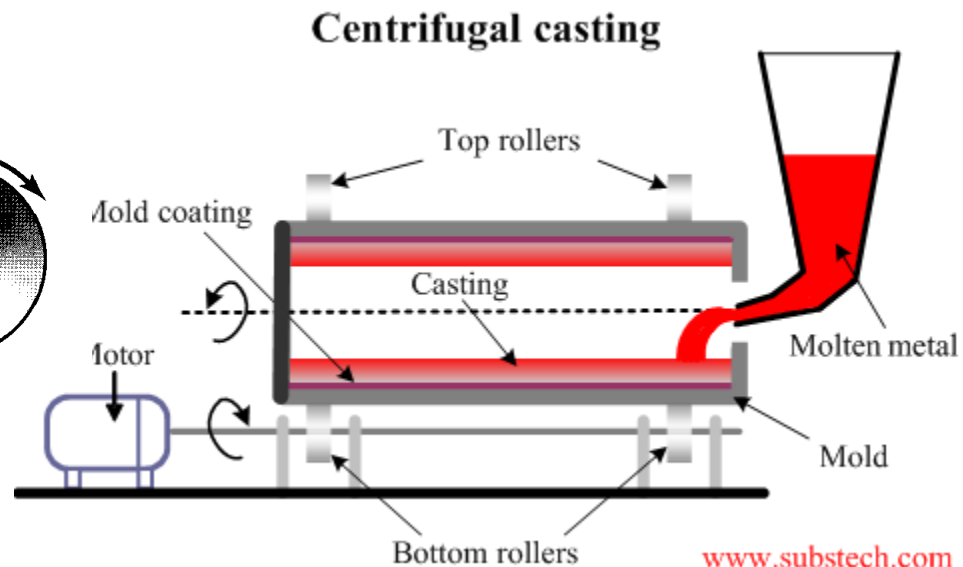
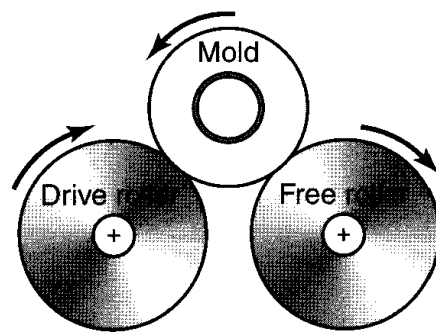
Pressure: 20-70 MPa



Pressure die casting

Fémalk Zrt.





Centrifugal Casting of Ductile Iron Pipe



	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

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							

- 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)



Steps

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



Processes

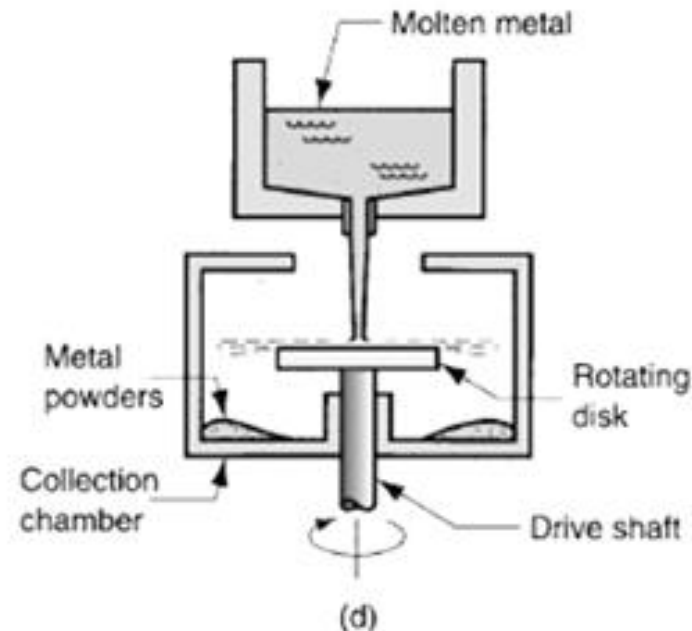
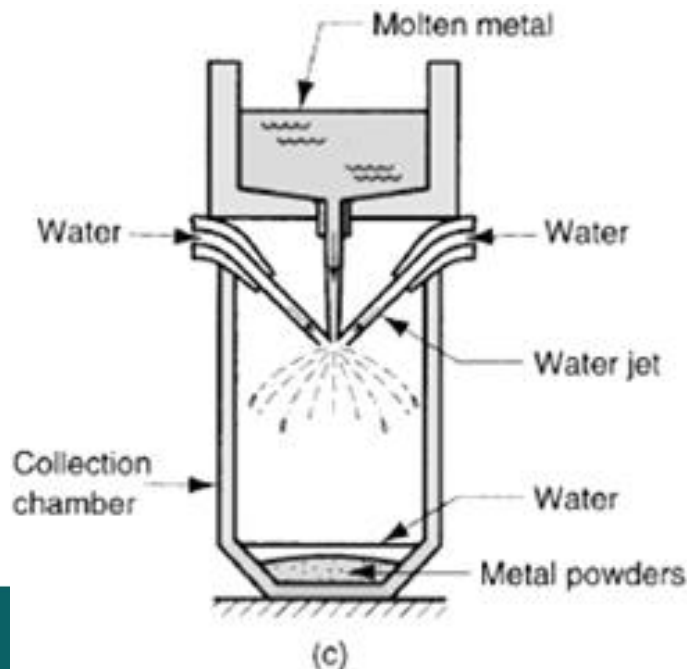
- Powder forging
Press and sinter + hot forging
- Hot isostatic pressing
Powder in sealed can, $0.7 T_{hom}$,
100 MPa
- Metal injection moulding
Powder + binder injection moulded (green),
heated (brown) and sintered
- Electric current assisted sintering
Electric current to densify powders
- Additive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

- 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.



- Die pressing

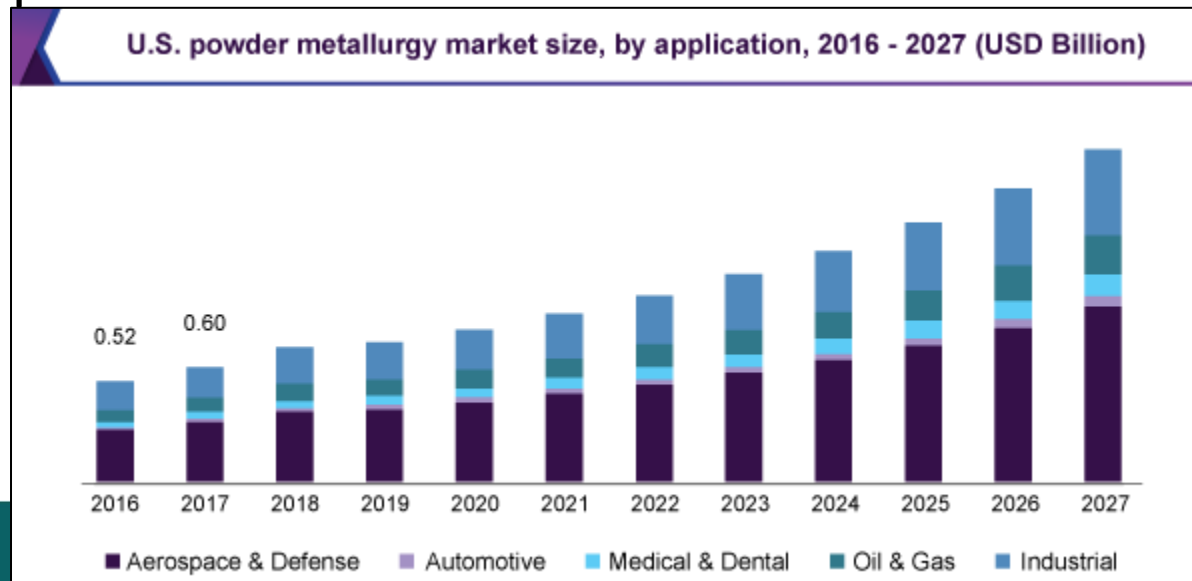
Presses are used (hydraulic, mechanical, servo-electrical)

- 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.



Powder Metallurgy



Thank you for your attention!

- <https://youtu.be/S07fPo45BvM>
- <https://youtu.be/UBeUp-oP7Lk>
- <https://youtu.be/WhS1ziBDxag>
- <https://youtu.be/TVsJIWEzZY8>
- <https://youtu.be/3G2sBqXkRT8>
- <https://youtu.be/N4-kfSD6XJI>