

Secondary Processing Steps

Forging: Hammering, pressing,
rolling, drawing,



Direct processing vs secondary processing

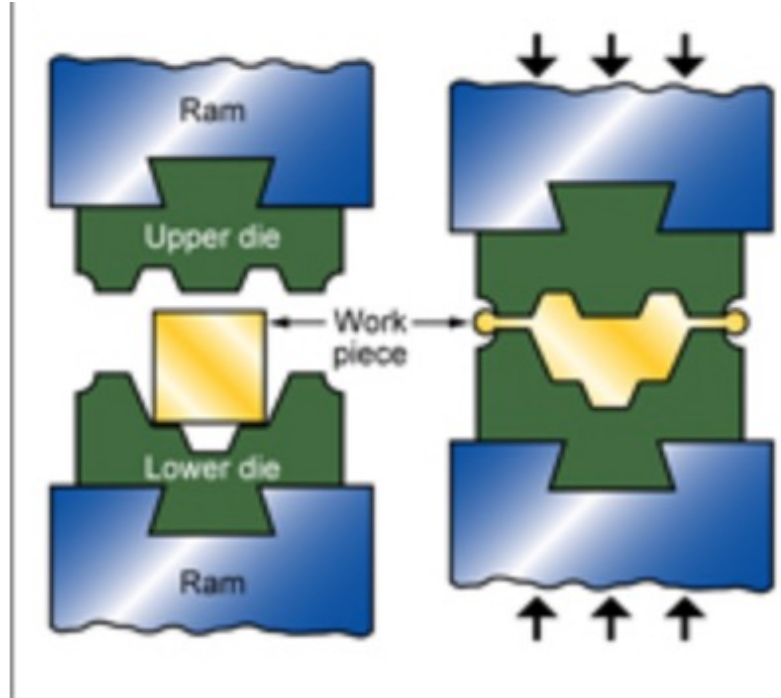
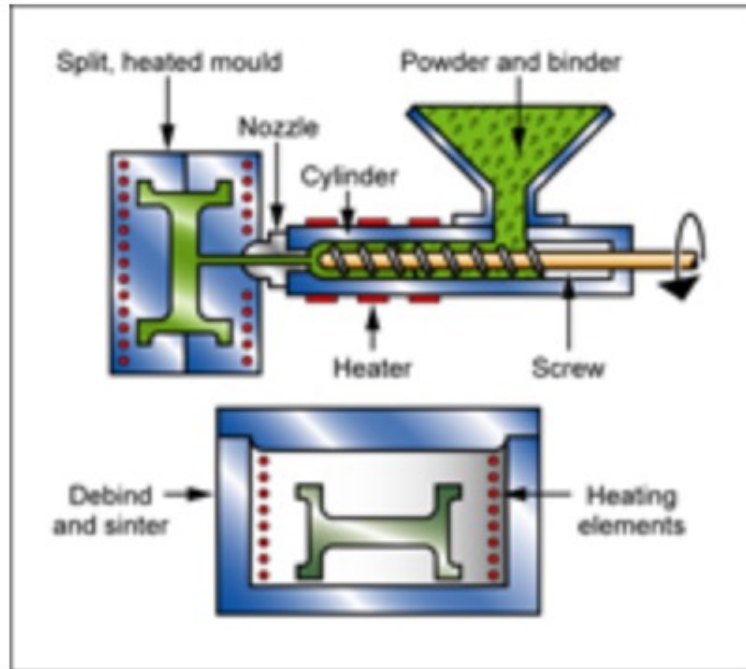
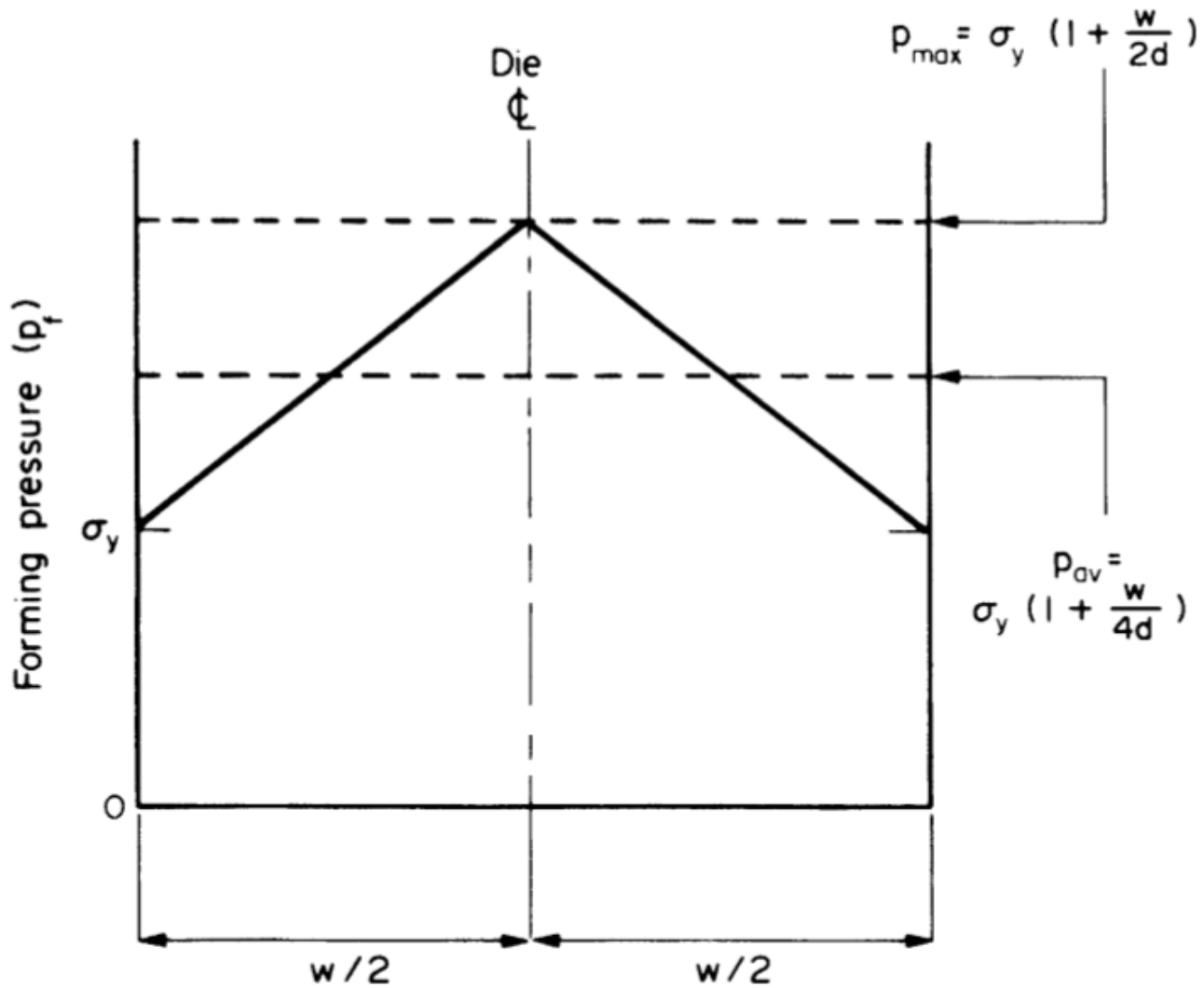


Diagram illustrating a forging process. A central workpiece is being compressed between two dies. The top die is labeled "Forging die" and the bottom die is labeled "Forging". A downward force F is applied to the top die, and an upward force F is applied to the bottom die. The width of the workpiece is labeled W .

v

Forming pressure

$$p = \sigma_y \left[1 + \frac{\left(\frac{w}{2} - x \right)}{d} \right]$$



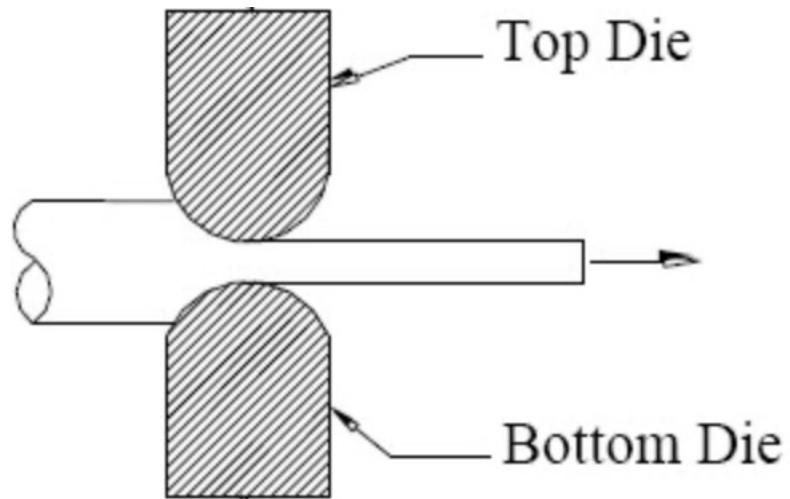
Maximum pressure at the center:

$$p_{max} = \sigma_y \left(1 + \frac{w}{2d} \right)$$

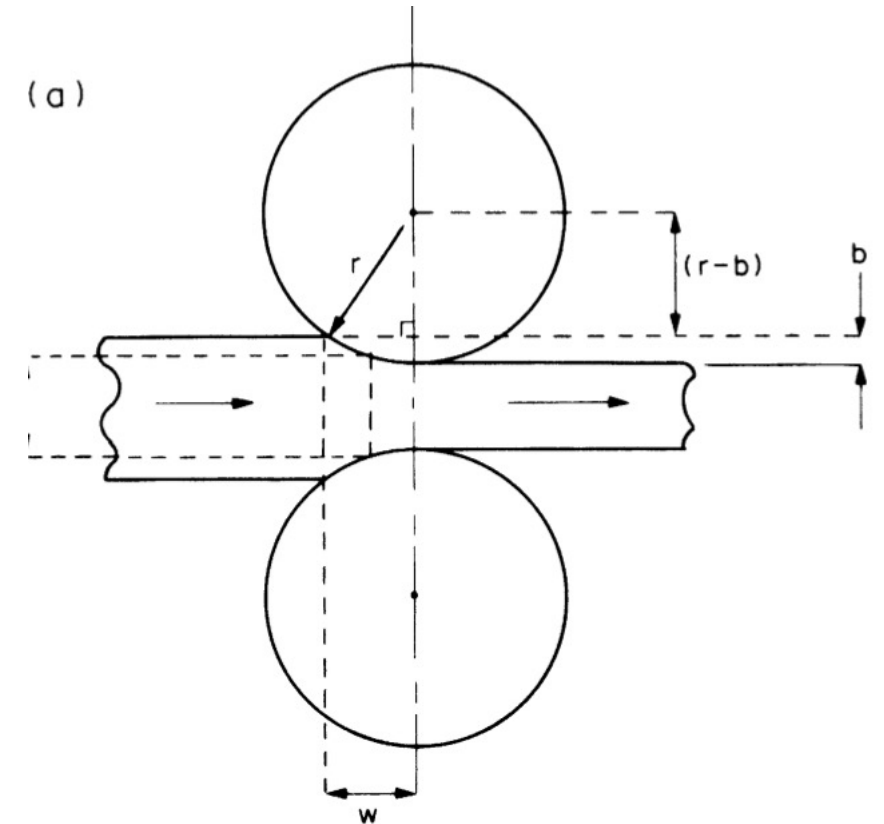
Efficient forging

- Forge at higher temperatures – smaller σ_y
- Have a smaller w/d ratio.

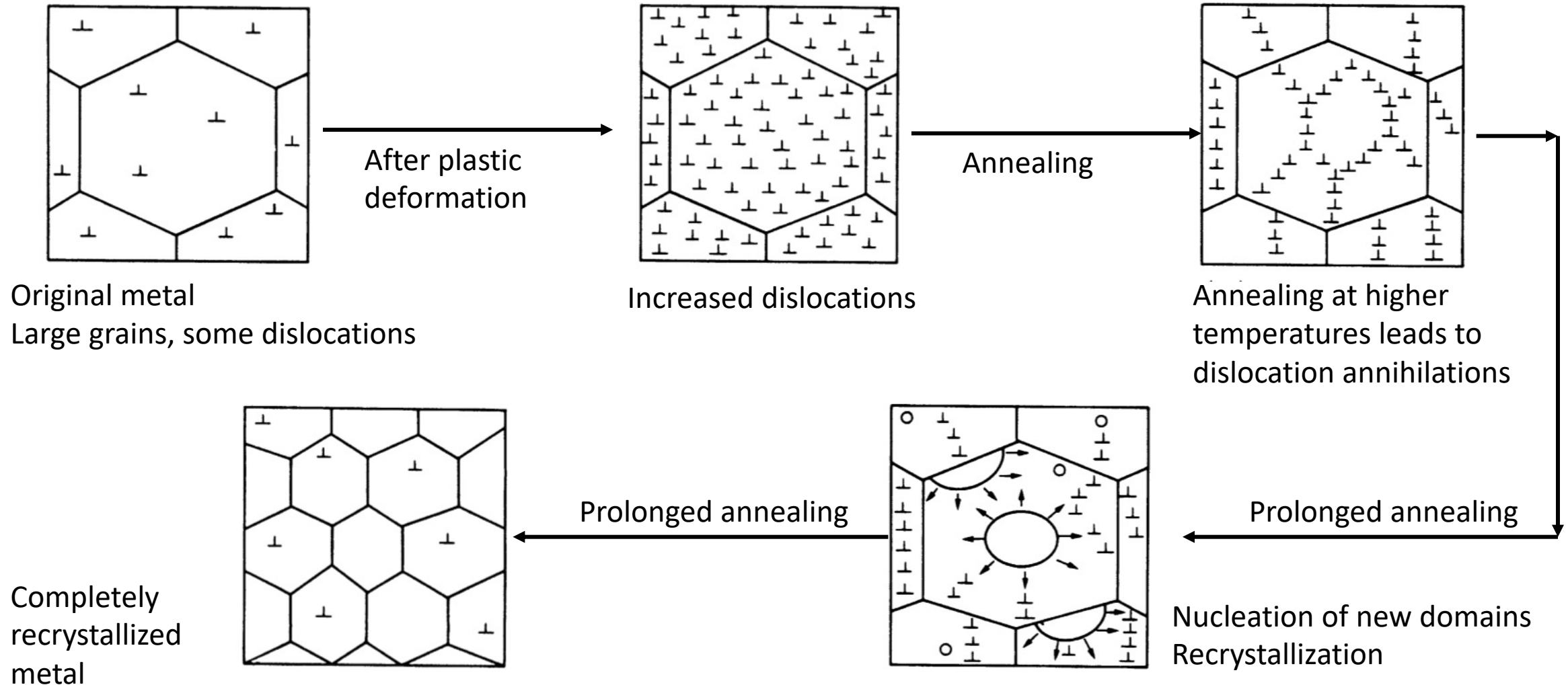
Drawing



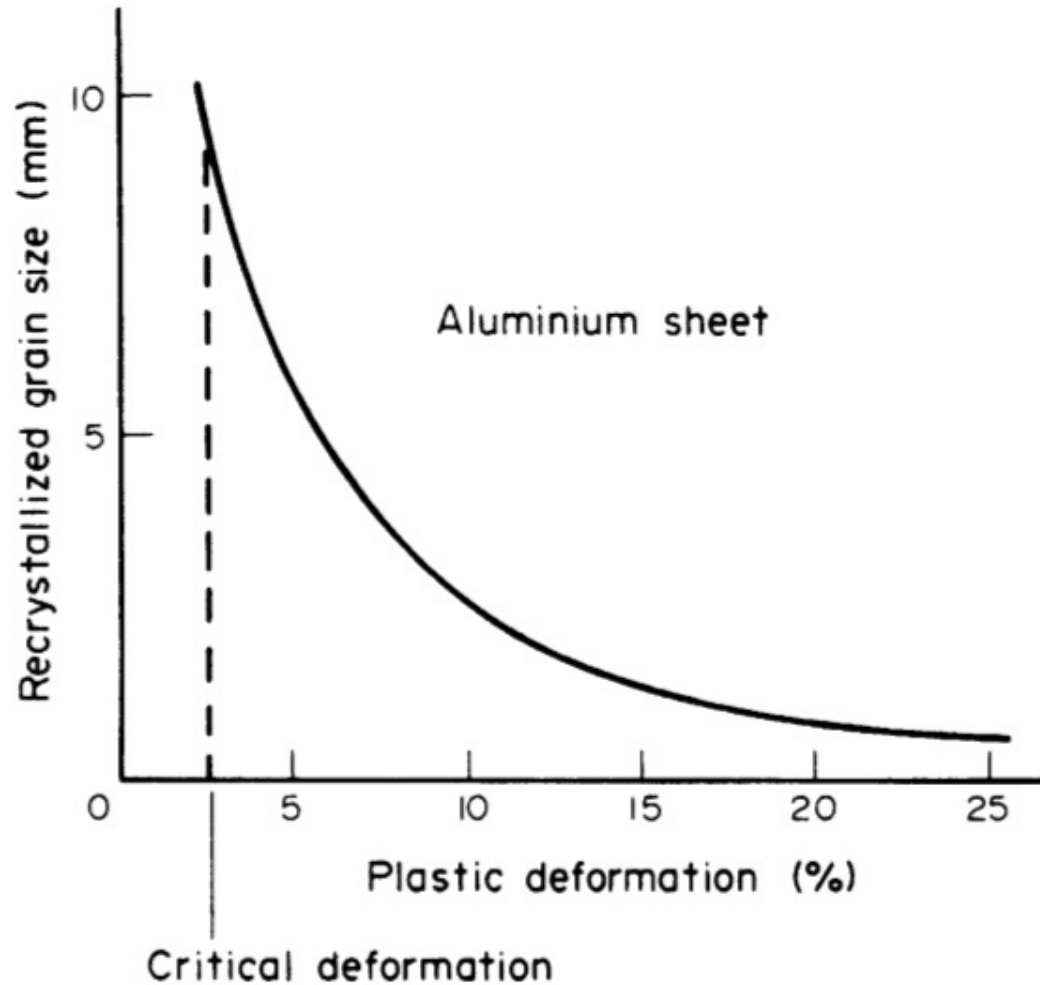
Rolling



Microstructure of Forging process

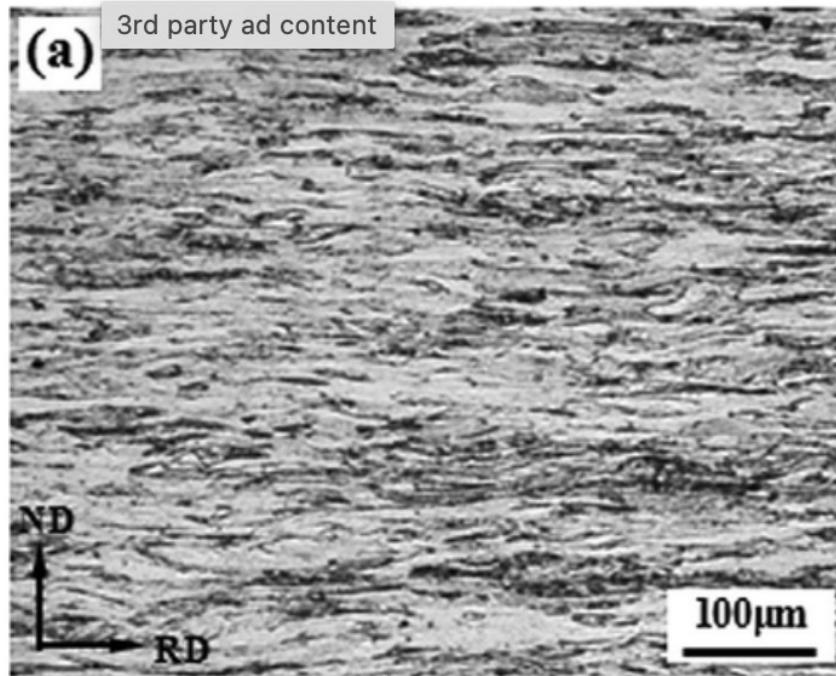


Work Hardening and Recrystallization

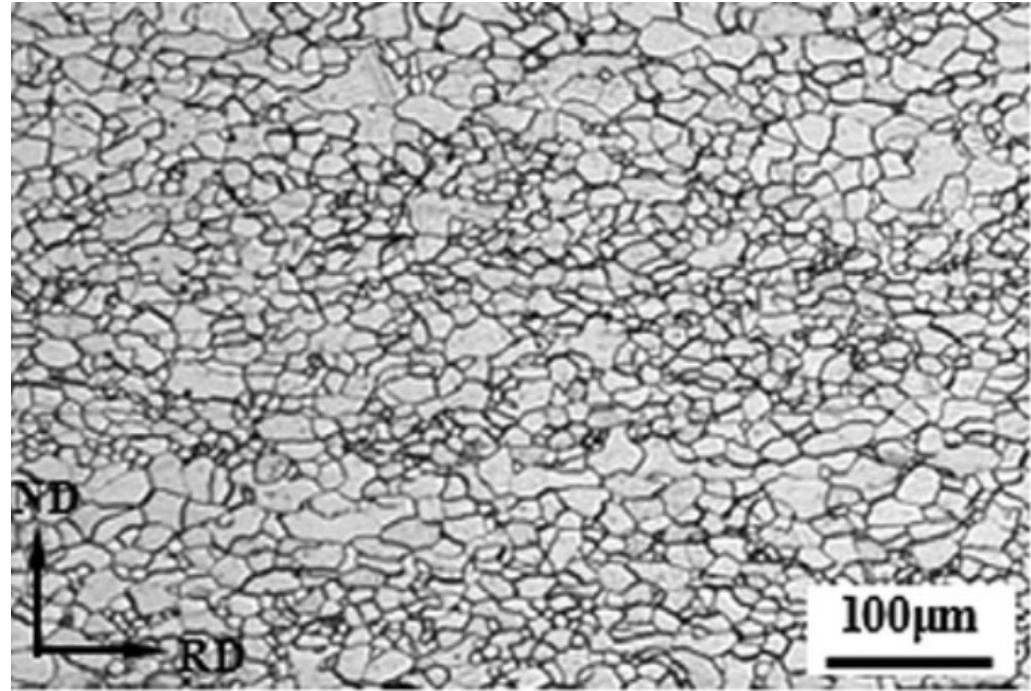


- Plastic deformations increases internal strain energy
- Metal hardens, loses ductility
- Recovery
 - Dislocations join to form low angle grain boundaries
- Recrystallization leads to smaller crystal grains

Effect of rolling and annealing of steel



As Cold Rolled



After annealing

Different types of forging

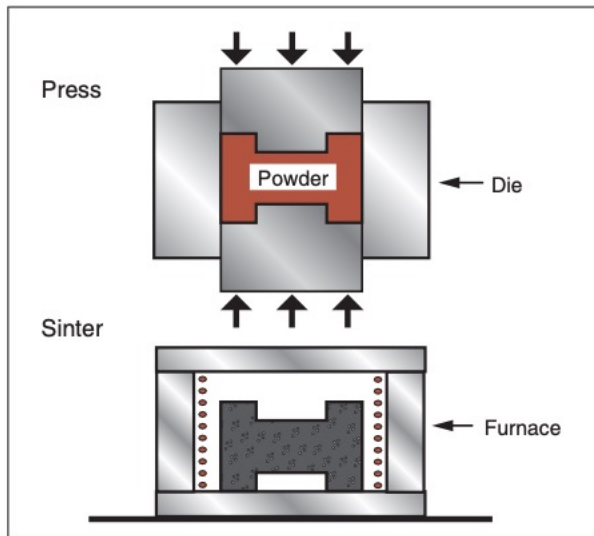
- Cold Forging

- Increases strength
- Reduce ductility
- Increase yield stress
- Decreased toughness
- Lower cost

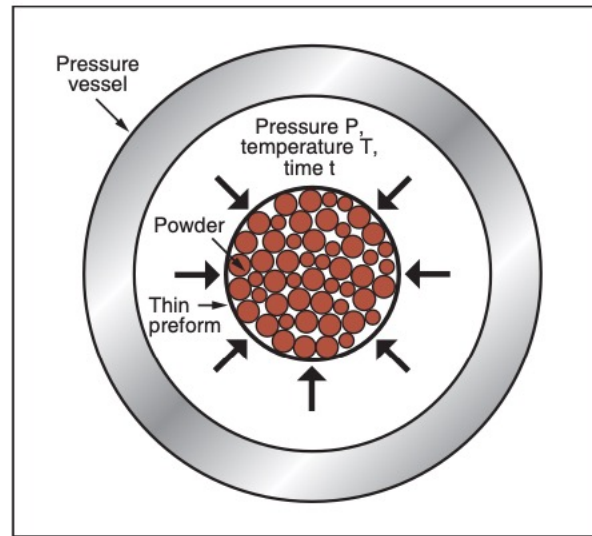
- Hot Forging

- Increased ductility
- Homogeneity
- Better surface finish
- Problems with scaling – surface oxidations
- Reduced strength
- Increased total cost

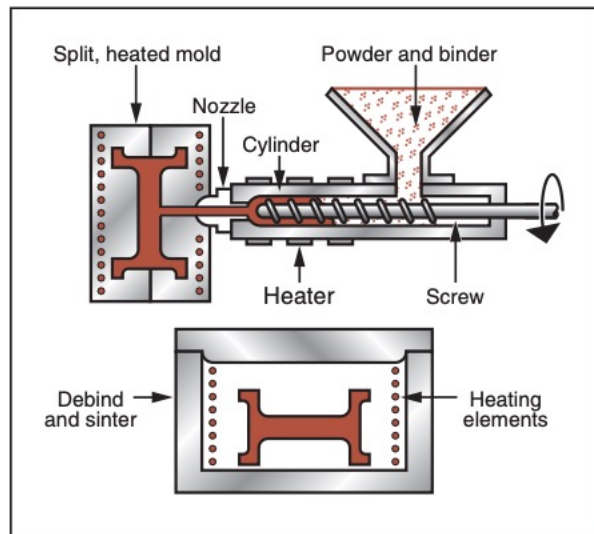
Other powder based techniques



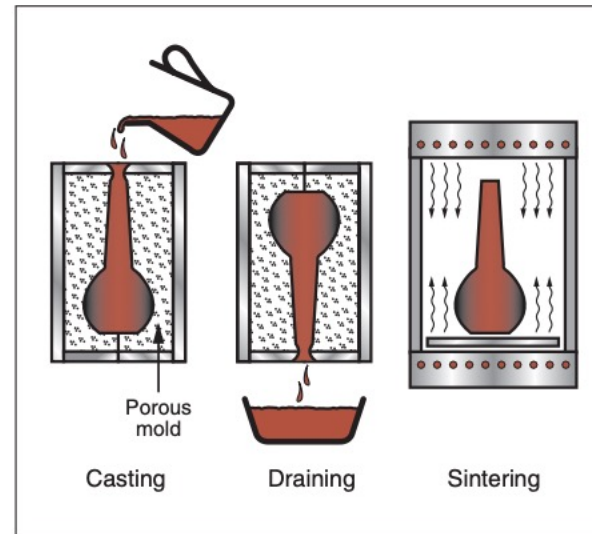
Die-pressing and sintering



Hot isostatic pressing



Powder injection molding



Slip casting

Homework:

List of polymer processing techniques
2 examples of primary and 2 examples of
secondary processing techniques.

Thermal treatment

- Many light alloys (Al, Mg..) derive strength from heat treatment
- Types of hardening
 - Solid Solution hardening
 - Age/precipitation hardening
 - Work hardening

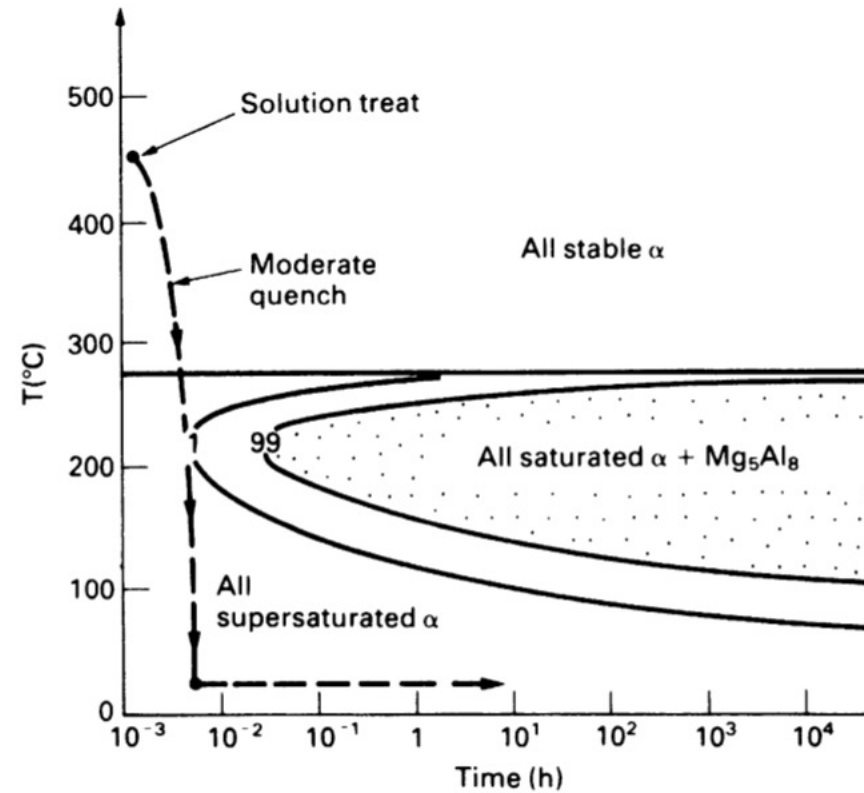
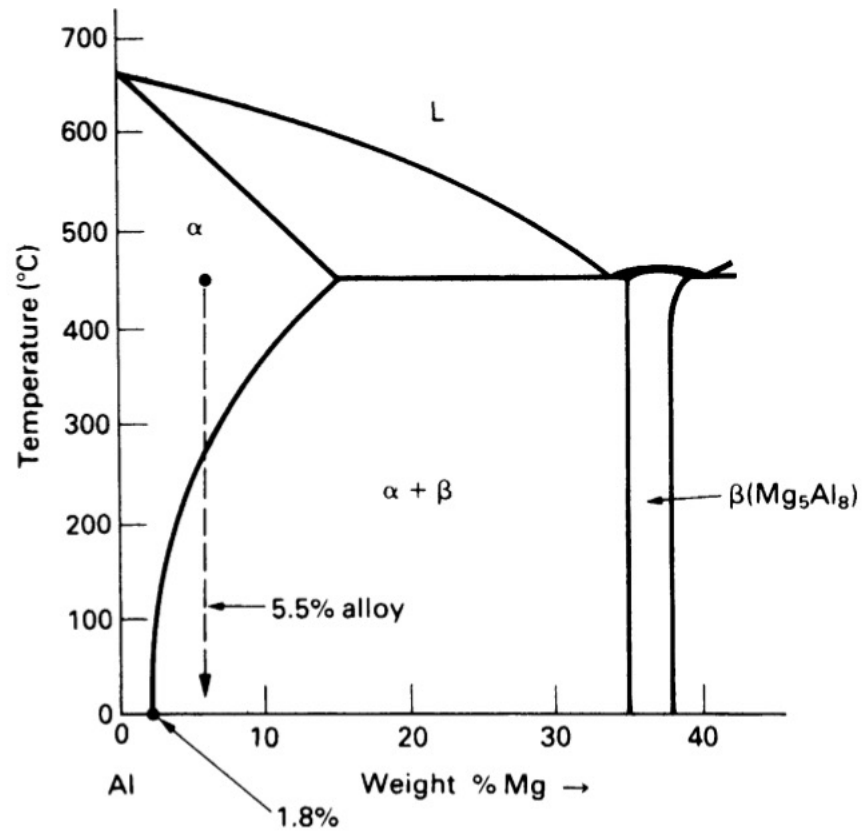
The light metals

<i>Metal</i>	<i>Density (Mg m^{-3})</i>	<i>T_m(°C)</i>	<i>Comments</i>
Titanium	4.50	1667	High T _m – excellent creep resistance.
Yttrium	4.47	1510	Good strength and ductility; scarce.
Barium	3.50	729	
Scandium	2.99	1538	Scarce.
Aluminium	2.70	660	
Strontium	2.60	770	Reactive in air/water.
Caesium	1.87	28.5	Creeps/melts; very reactive in air/water.
Beryllium	1.85	1287	Difficult to process; very toxic.
Magnesium	1.74	649	
Calcium	1.54	839	Reactive in air/water.
Rubidium	1.53	39	Creep/melt; very reactive in air/water.
Sodium	0.97	98	
Potassium	0.86	63	
Lithium	0.53	181	

↑

<i>Alloy</i>	<i>Density ρ (Mg m^{-3})</i>	<i>Young's modulus E (GPa)</i>	<i>Yield strength σ_y (MPa)</i>	<i>E/ρ^*</i>	<i>E^{1/2}/ρ^*</i>	<i>E^{1/3}/ρ^*</i>	<i>σ_y/ρ^*</i>	<i>Creep temperature (°C)</i>
Al alloys	2.7	71	25–600	26	3.1	1.5	9–220	150–250
Mg alloys	1.7	45	70–270	25	4.0	2.1	41–160	150–250
Ti alloys	4.5	120	170–1280	27	2.4	1.1	38–280	400–600
(Steels)	(7.9)	(210)	(220–1600)	27	1.8	0.75	28–200	(400–600)

Solid Solution hardening



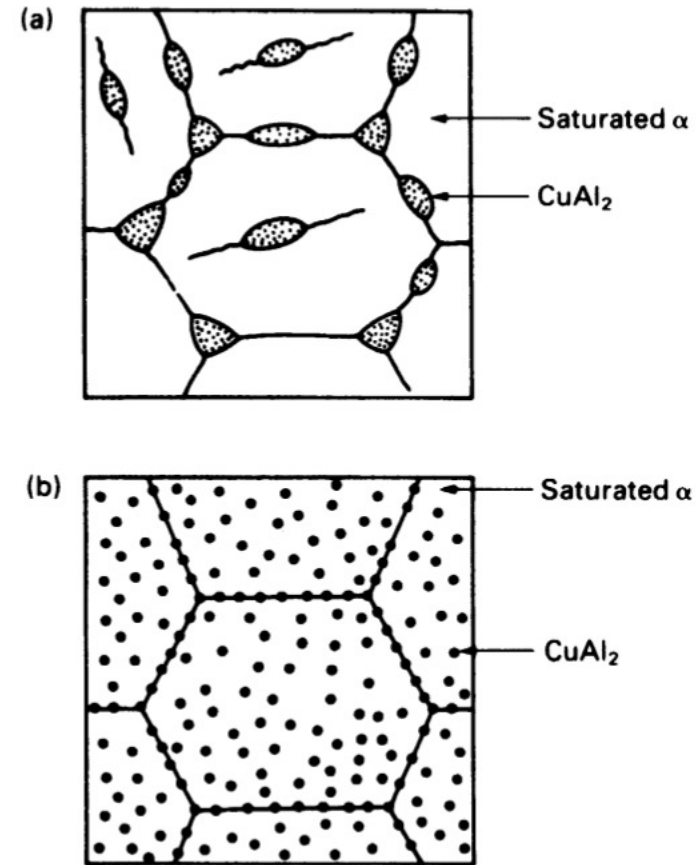
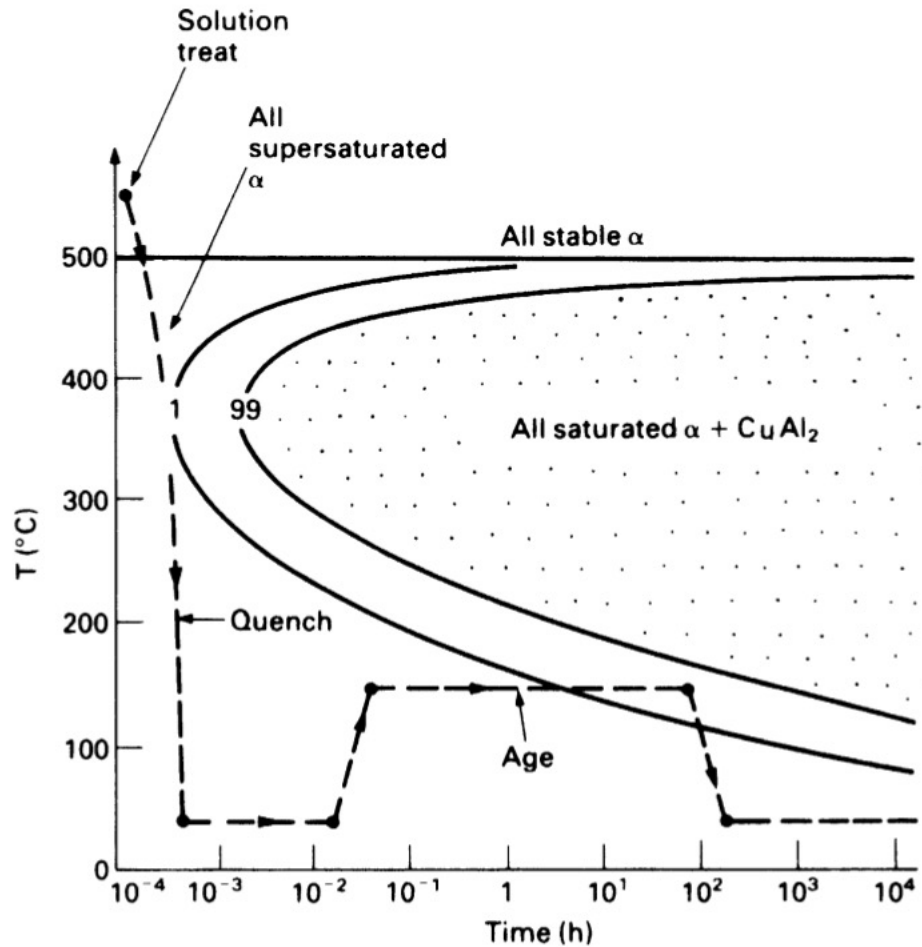
At room temperature

Mg Solubility in Al – 1.8%

However, if we cool a 5.5% Mg alloy relatively quickly, the resulting solid solution is supersaturated.

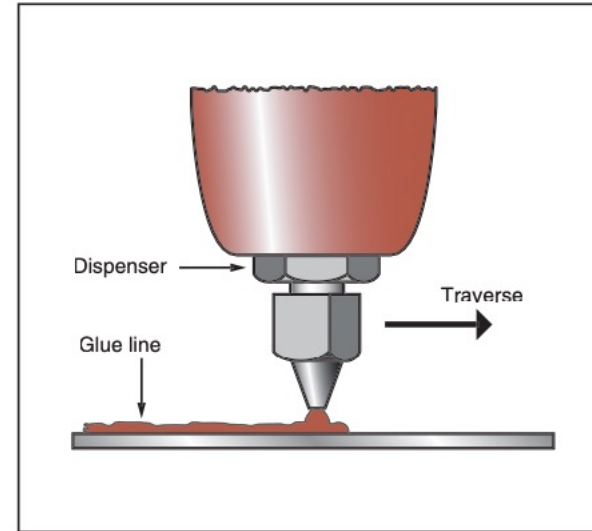
This gives increased stiffness.

Age precipitation

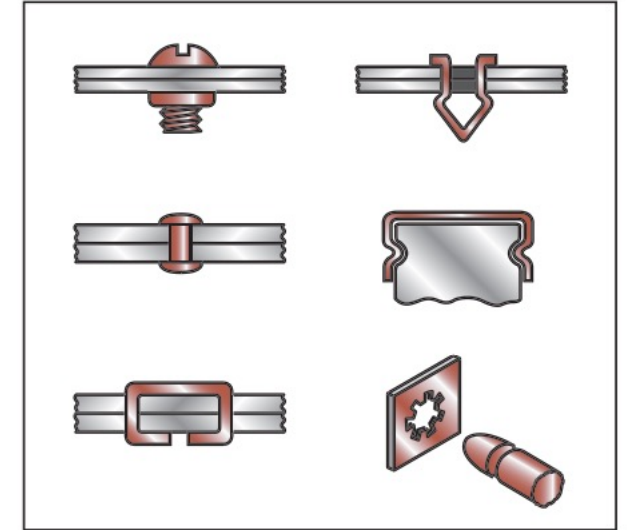


Joining Techniques

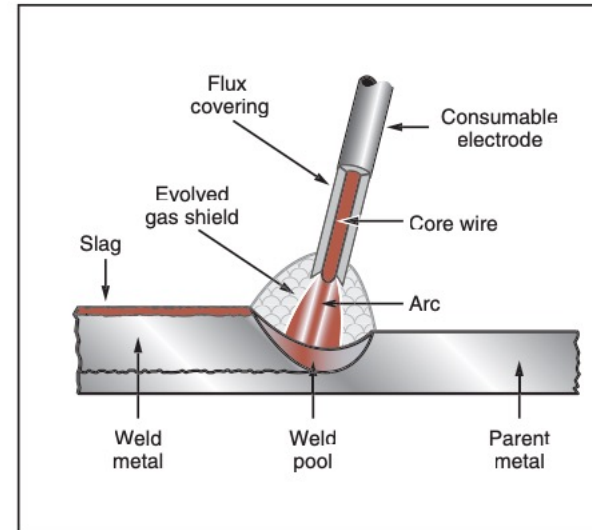
- Welding
 - Mostly for metals and polymers
 - Weldability is a combination of low thermal conductivity and thermal expansion coefficient
 - Hydrogen embrittlement is a problem: (oxide formation leads to atomic hydrogen induction into the metal)



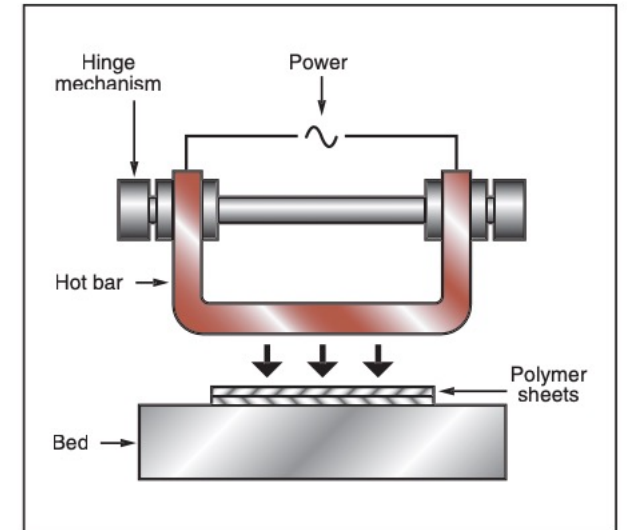
Adhesives



Fasteners



Welding: manual metal arc

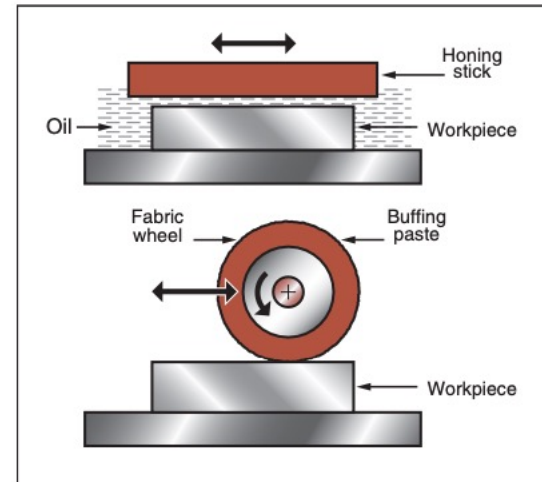


Welding: hot bar polymer welding

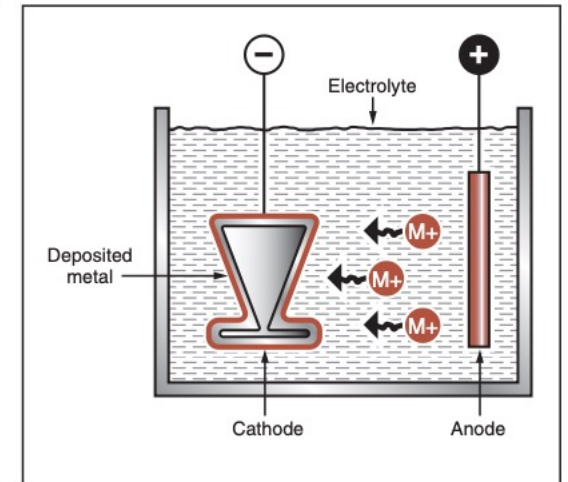
Finishing Processes

Surface treatments for

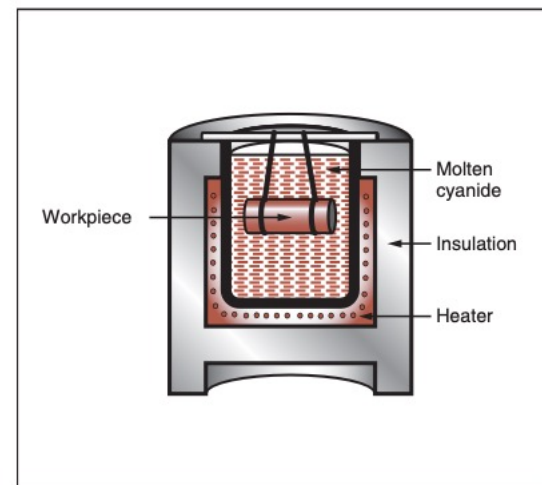
1. Visual appeal
2. Part inter-operability
3. Corrosion resistance



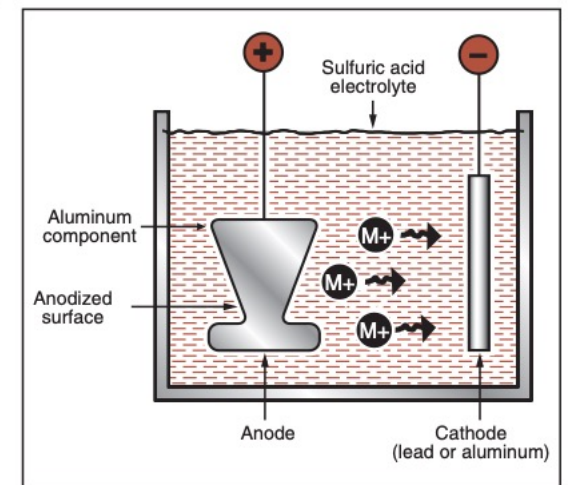
Mechanical polishing



Electro-plating



Heat treatment: carburizing



Anodizing

Eg: Anodization

