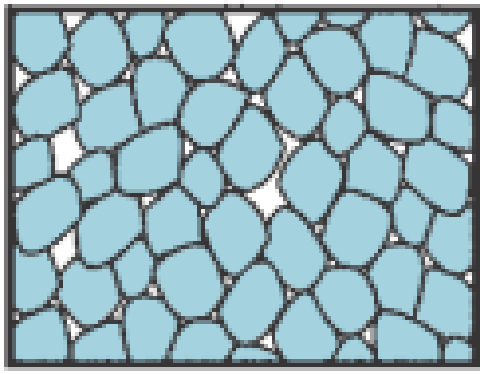
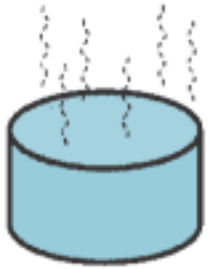
Lecture # 7

POWDER METALLURGY

Sintering





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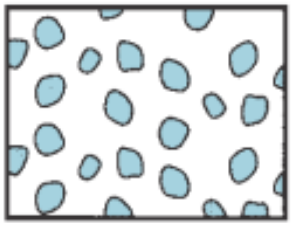
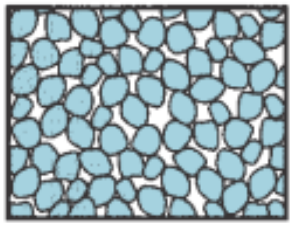
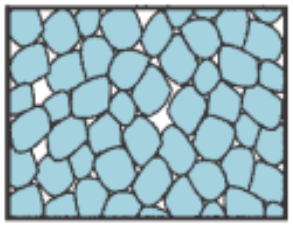
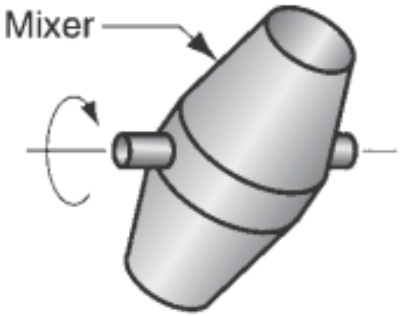
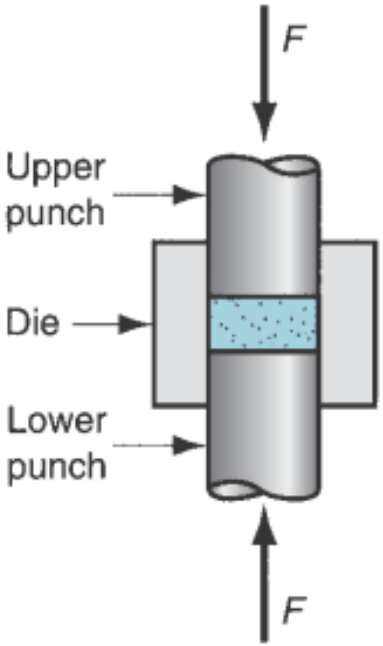
PM Sequence

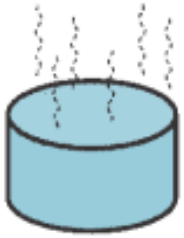












Mixing

Compaction

Sintering

Sintering

- In the sintering operation, the pressed-powder compacts are heated in a controlled atmosphere to right below the melting point.
- Heat treatment to bond the metallic particles, thereby increasing strength and hardness.
- Usually carried out at between 70% and 90% of the metal's melting point.
- Part shrinkage occurs during sintering due to pore size reduction

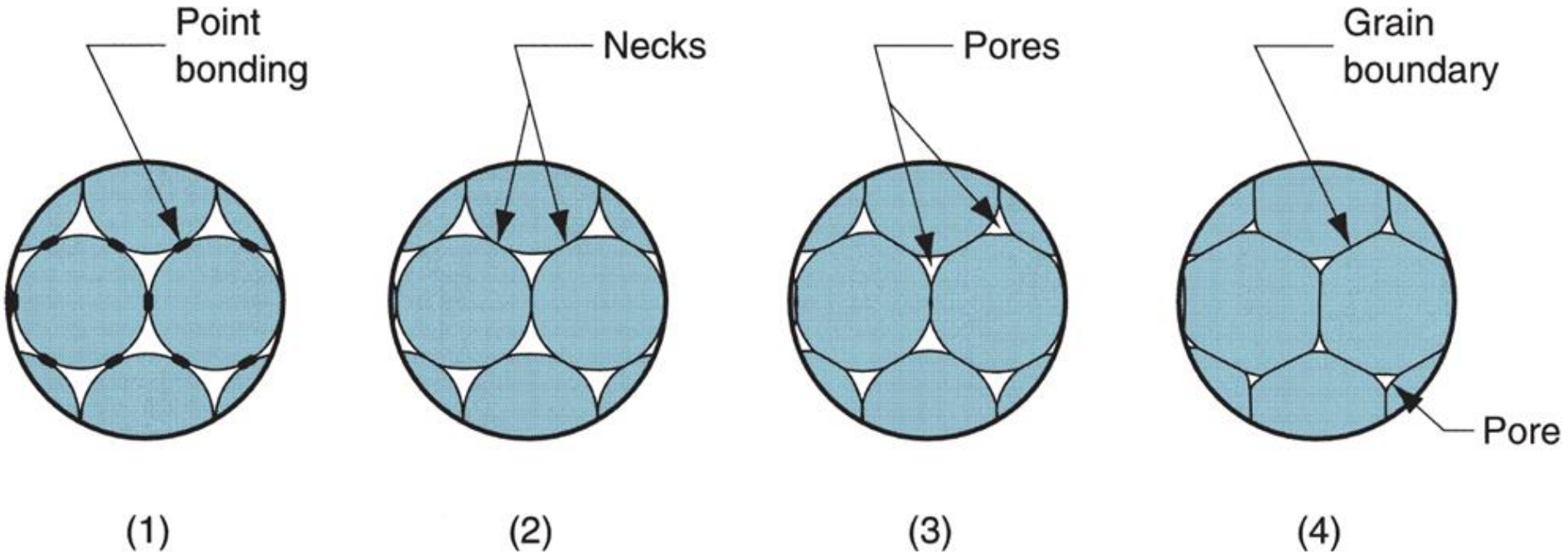
Sintering Stages

Three stages of sintering

- Burn-off (purge)- combusts any air and removes lubricants or binders that would interfere with good bonding.
- High-temperature- desired solid-state diffusion and bonding occurs.
- Cooling period- lowers the temperature of the products in a controlled atmosphere.

All three stages must be conducted in oxygen-free conditions

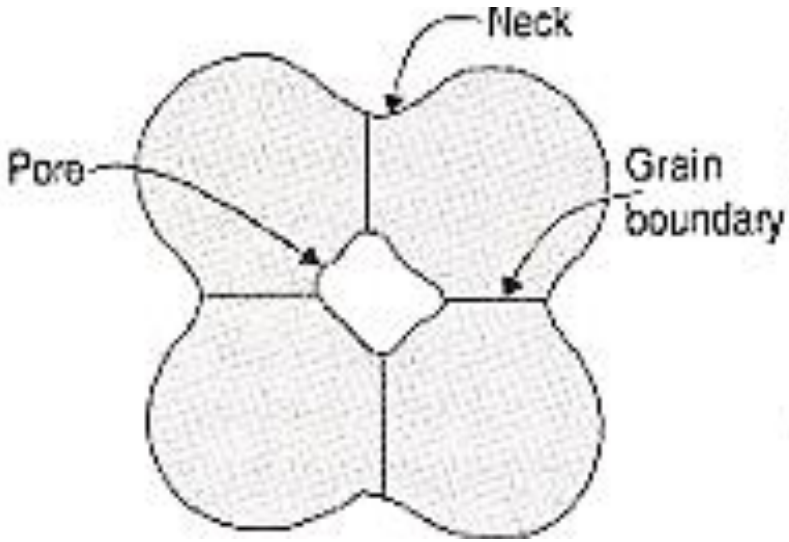
Sintering on a microscopic scale



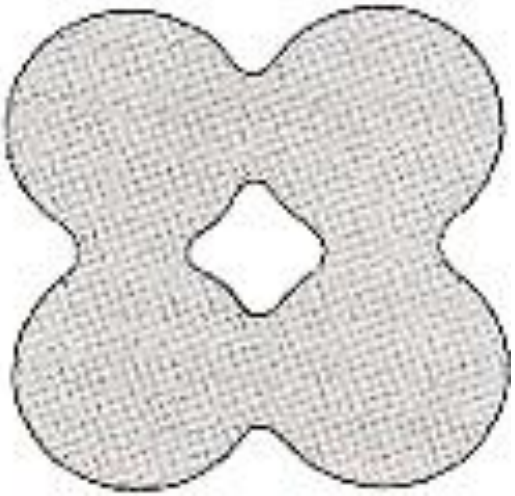
(1) particle bonding is initiated at contact points; (2) contact points grow into "necks"; (3) the pores between particles are reduced in size; and (4) grain boundaries develop between particles in place of the necked regions

Sintering on a microscopic scale

Particles in contact

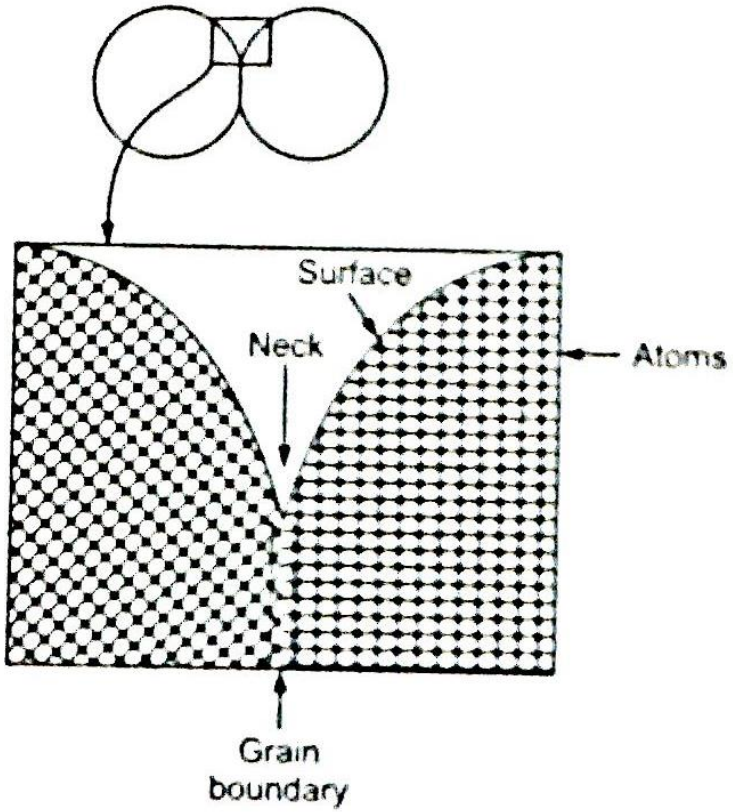


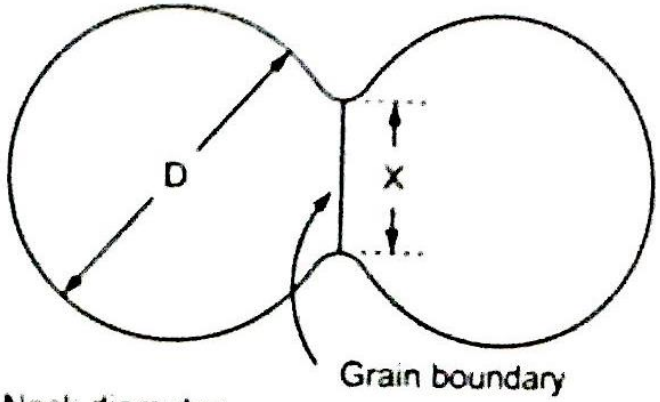
Formation of necks, grain boundaries, pores



Final sintered geometry

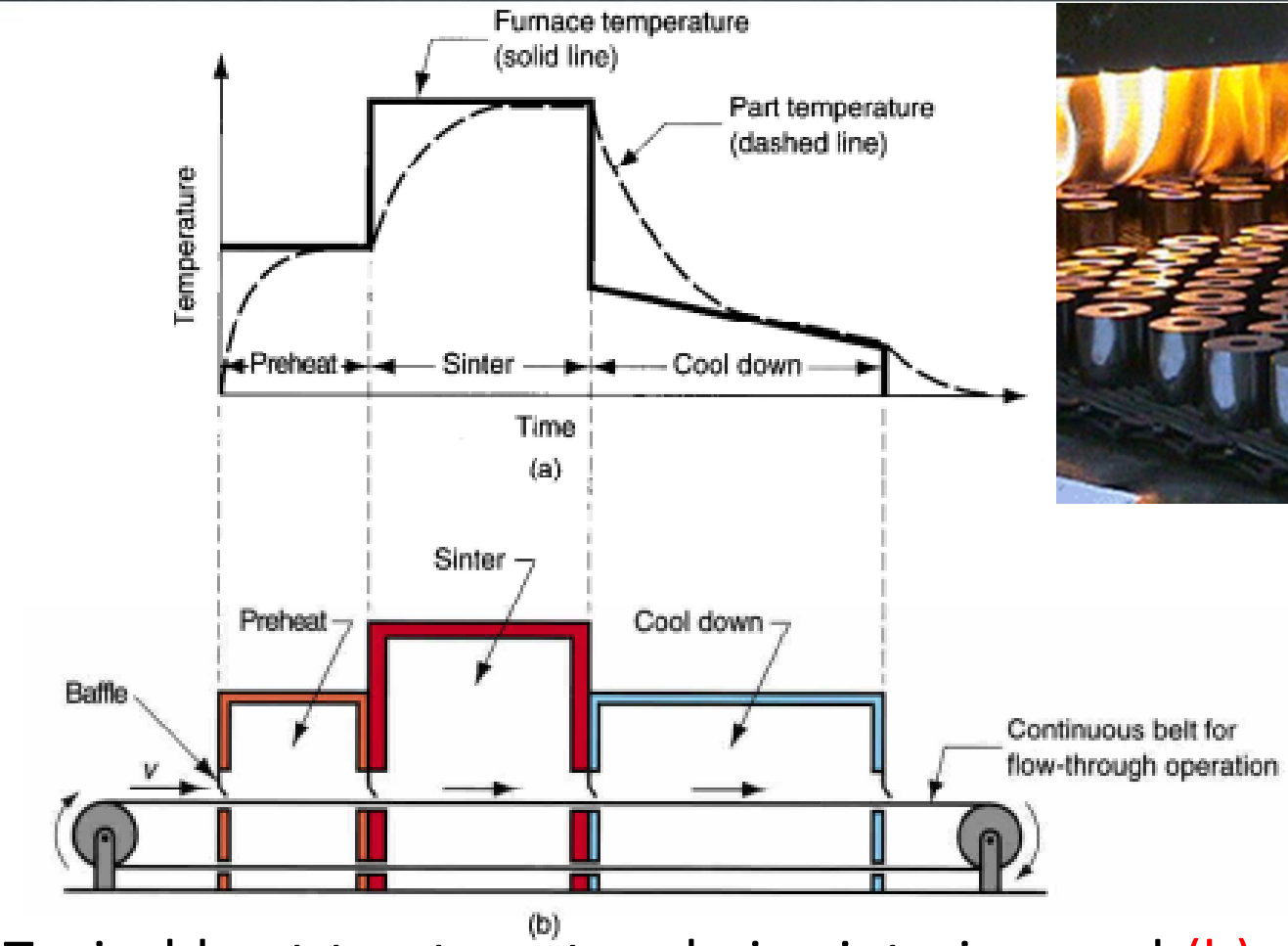
Interface between particles





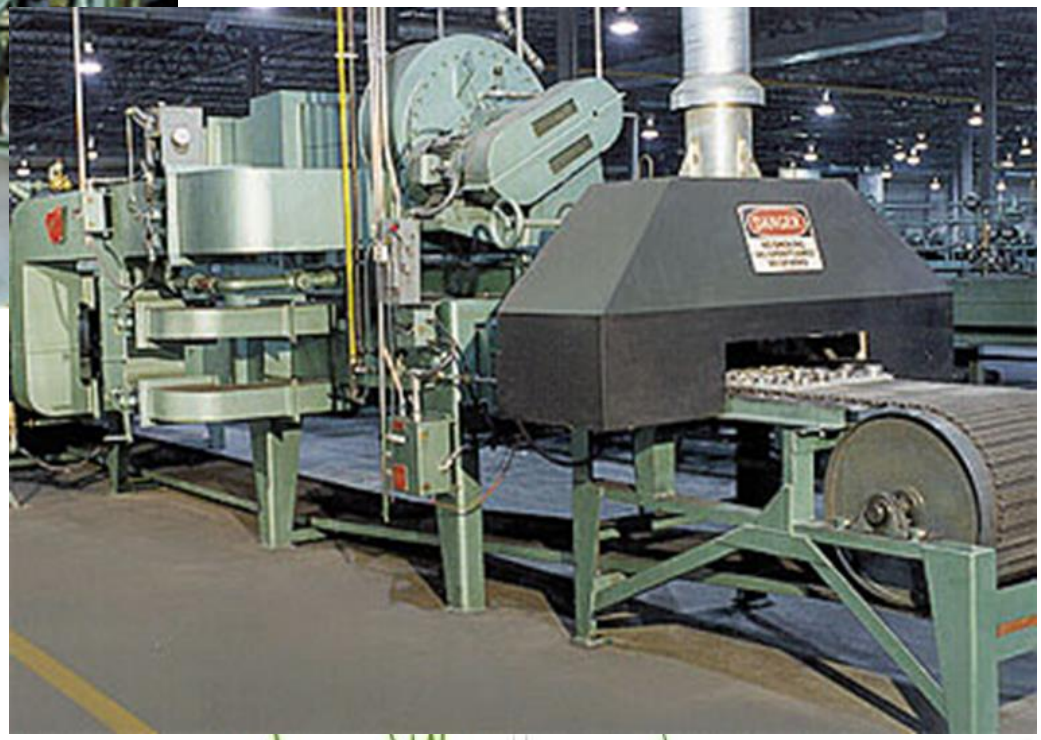
X = Neck diameter
D = Particle diameter
X/D = Neck size ratio

Heat cycle in sintering



(a) Typical heat treatment cycle in sintering; and (b) schematic cross-section of a continuous sintering furnace

Examples of Sintering Production Lines

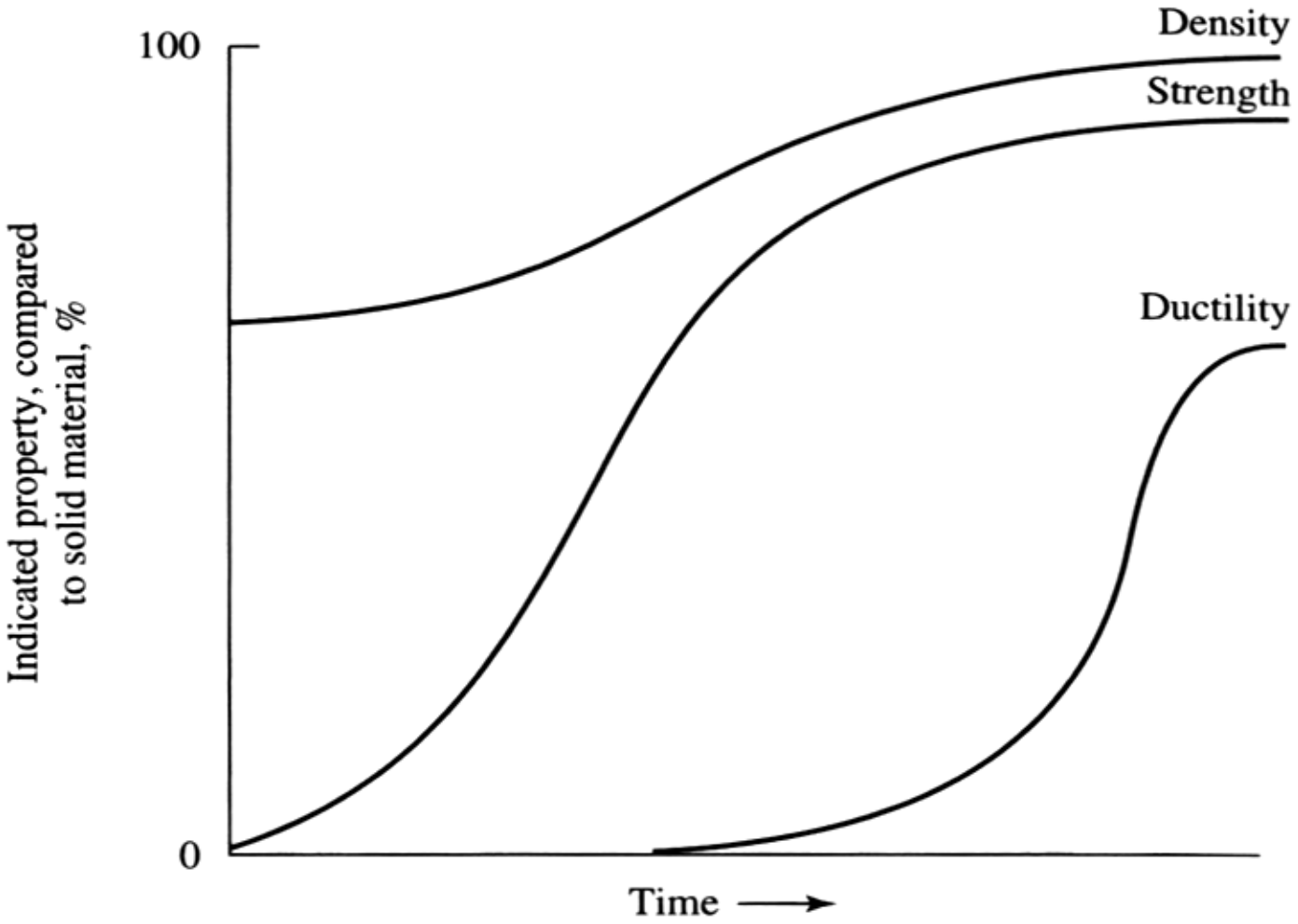


Sintering Time and Temperature for Metals

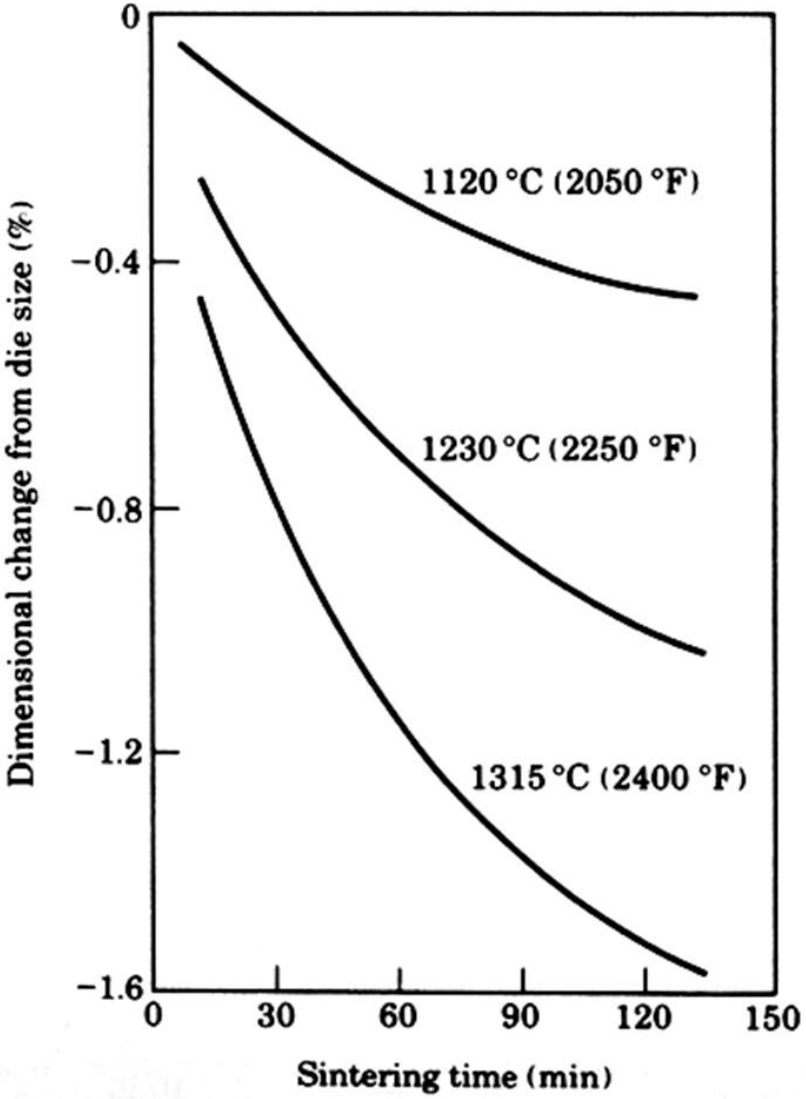
Sintering Temperature and Time for Various Metals

Material	Temperature (°C)	Time (min)
Copper, brass, and bronze	760-900	10-45
Iron and iron-graphite	1000-1150	8-45
Nickel	1000-1150	30-45
Stainless steels	1100-1290	30-60
Alnico alloys (for permanent magnets)	1200-1300	120-150
Ferrites	1200-1500	10-600
Tungsten carbide	1430-1500	20-30
Molybdenum	2050	120
Tungsten	2350	480
Tantalum	2400	480

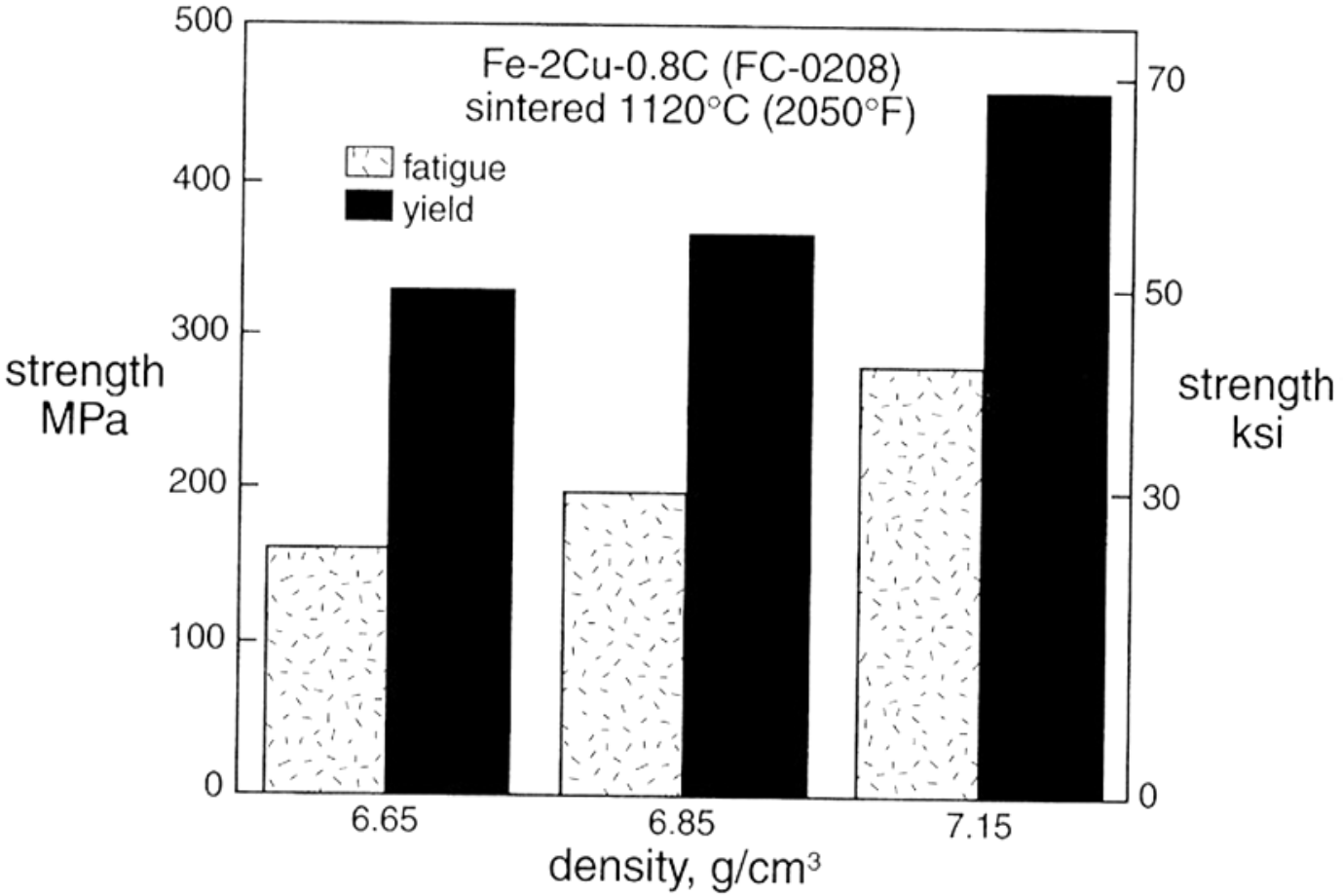
Final part properties drastically affected



Dimensions of part are affected



Strength & Density



Strength of sintered structures as related to density, showing that the strength is higher when the density is higher (less residual porosity)

Finishing operations

A number of secondary and finishing operations can be applied after sintering, some of them are:

- Sizing: cold pressing to improve dimensional accuracy
- Coining: cold pressing to press details into surface
- Impregnation: oil fills the pores of the part
- Infiltration: pores are filled with a molten metal
- Heat treating, plating, painting

Impregnation

- The term used when oil or other fluid is permeated into the pores of a sintered PM part.
- Common products are oil-impregnated bearings, gears, and similar components.
- An alternative application is when parts are impregnated with polymer resins that seep into the pore spaces in liquid form and then solidify to create a pressure tight part.

Infiltration

An operation in which the pores of the PM part are filled with a molten metal

- The melting point of the filler metal must be below that of the PM part.
- Involves heating the filler metal in contact with the sintered component so capillary action draws the filler into the pores.
- The resulting structure is relatively nonporous, and the infiltrated part has a more uniform density, as well as improved toughness and strength


Thank You!