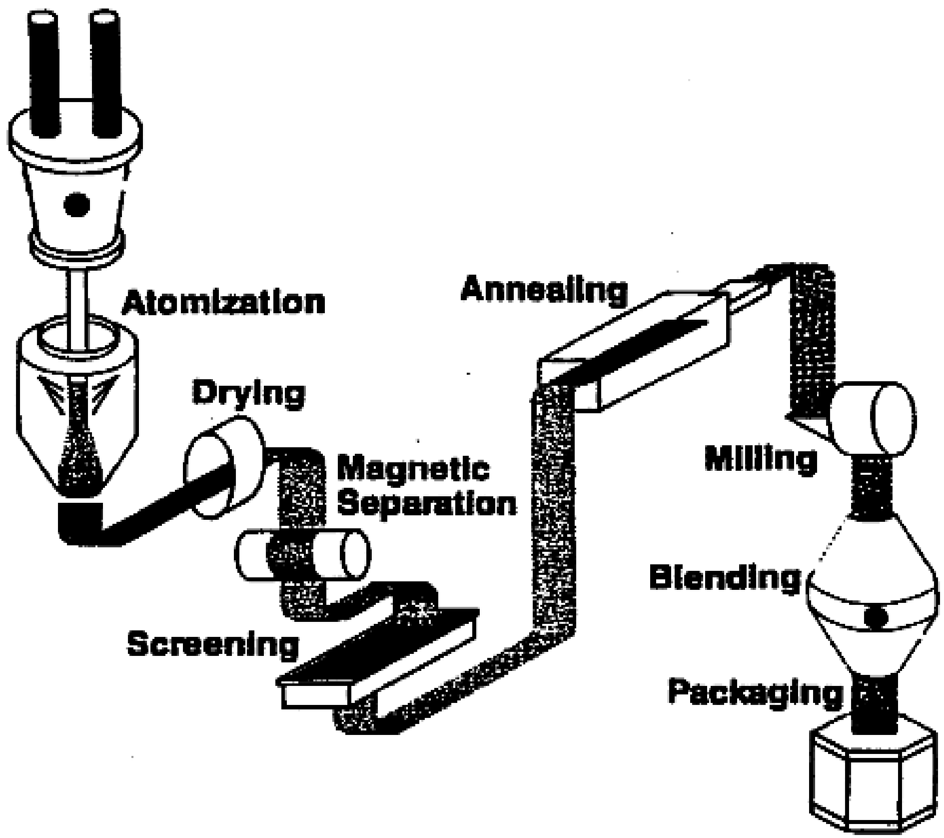
Mixing

- Elemental, partially alloyed or pre-alloyed metal powders are first blended with lubricants to produce a homogeneous mixture.



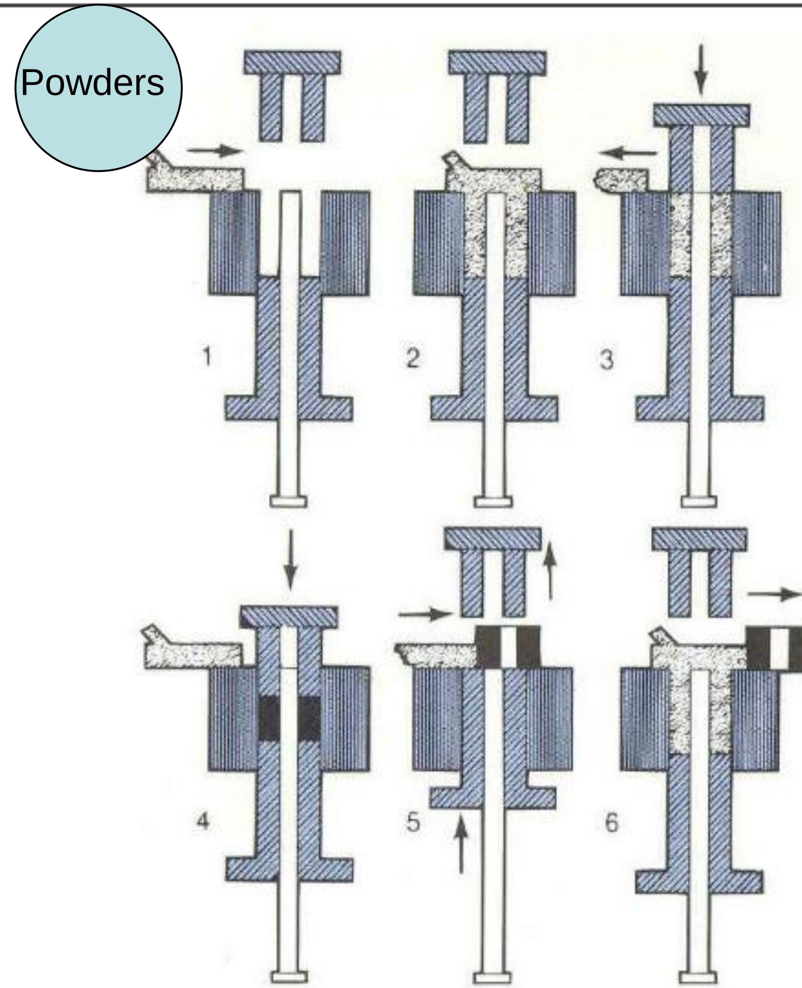
Compaction

- A controlled amount of a mixed powder is gravity fed into a precision die and then compacted. Compaction occurs at room temperature, at a pressure range of 25-50 tons per sq. in.
- Compacting the loose powder produces a "green compact" which, with conventional pressing techniques, has the size and shape of the finished part when ejected from the press. Green compacts have sufficient strength for in-process handling.
- Typical compaction techniques use rigid dies, set into mechanical or hydraulic presses.

Conventional Mechanical Press

Compaction Cycle

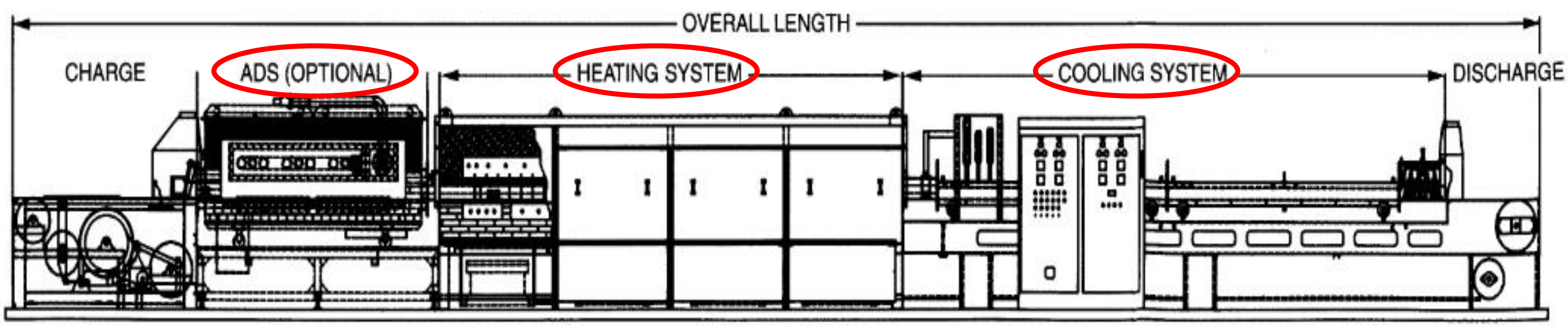
1. Cycle Start
2. Charge die w/powder
3. Compaction begins
4. Compaction complete
5. Ejection of compact
6. Recharging of die



Sintering

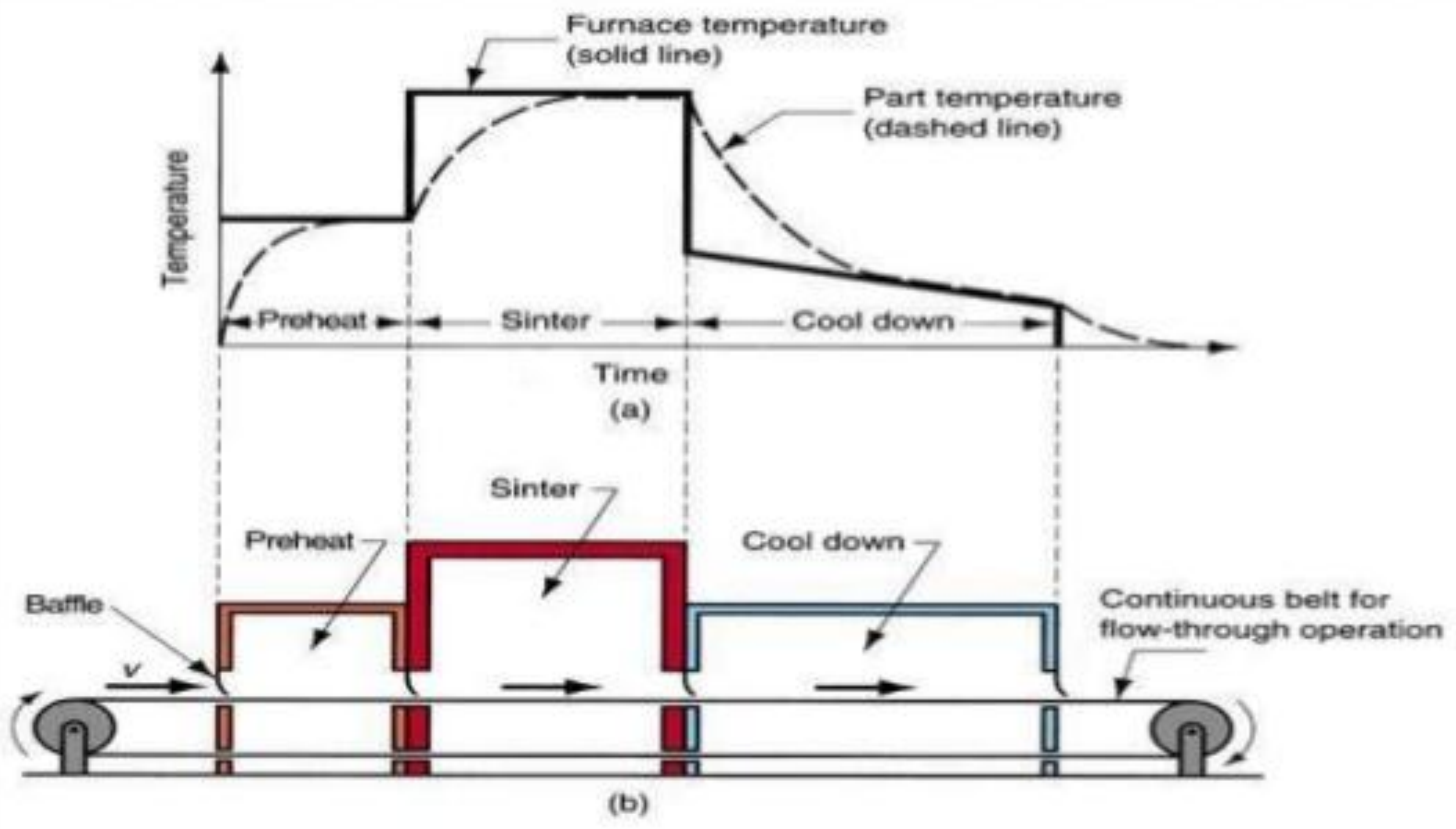
- Typically, the "Green compact" is placed on a mesh belt which then moves slowly through a controlled atmosphere furnace.
- The parts are heated below the melting point of base metal, held at the sintering temperature, then cooled.
- Basically, a solid state process, sintering transforms compacted mechanical bonds between powder particles into metallurgical bond.
- Typical sintering temperatures for ferrous based metals range 1120-1150 ºC.
- Standard cycle times range from 2-3 hours.

Conventional Furnace Profile

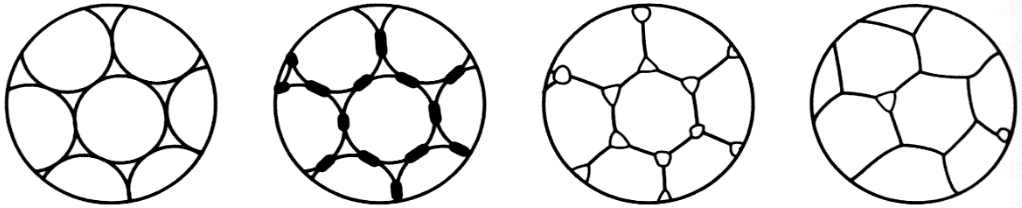


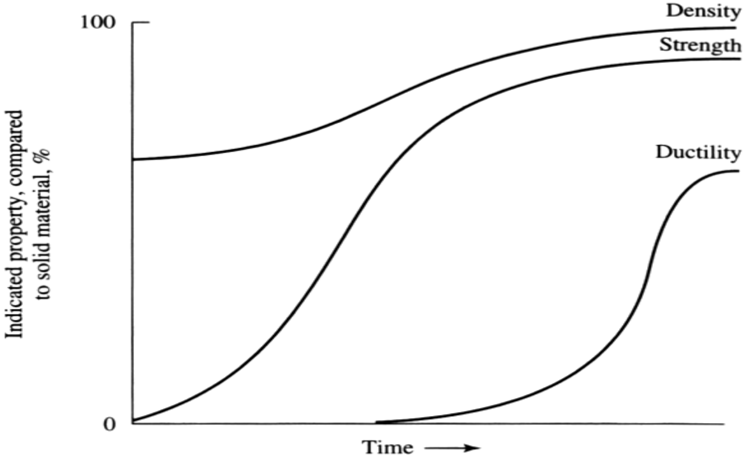
Typical sintering furnace configuration

Sintering Cycle and Furnace



- Parts are heated to 0.7~0.9 T_m.
- Transforms compacted mechanical bonds to much stronger metallic bonds.

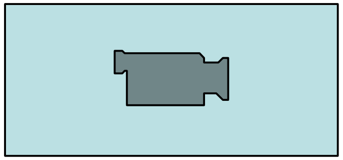


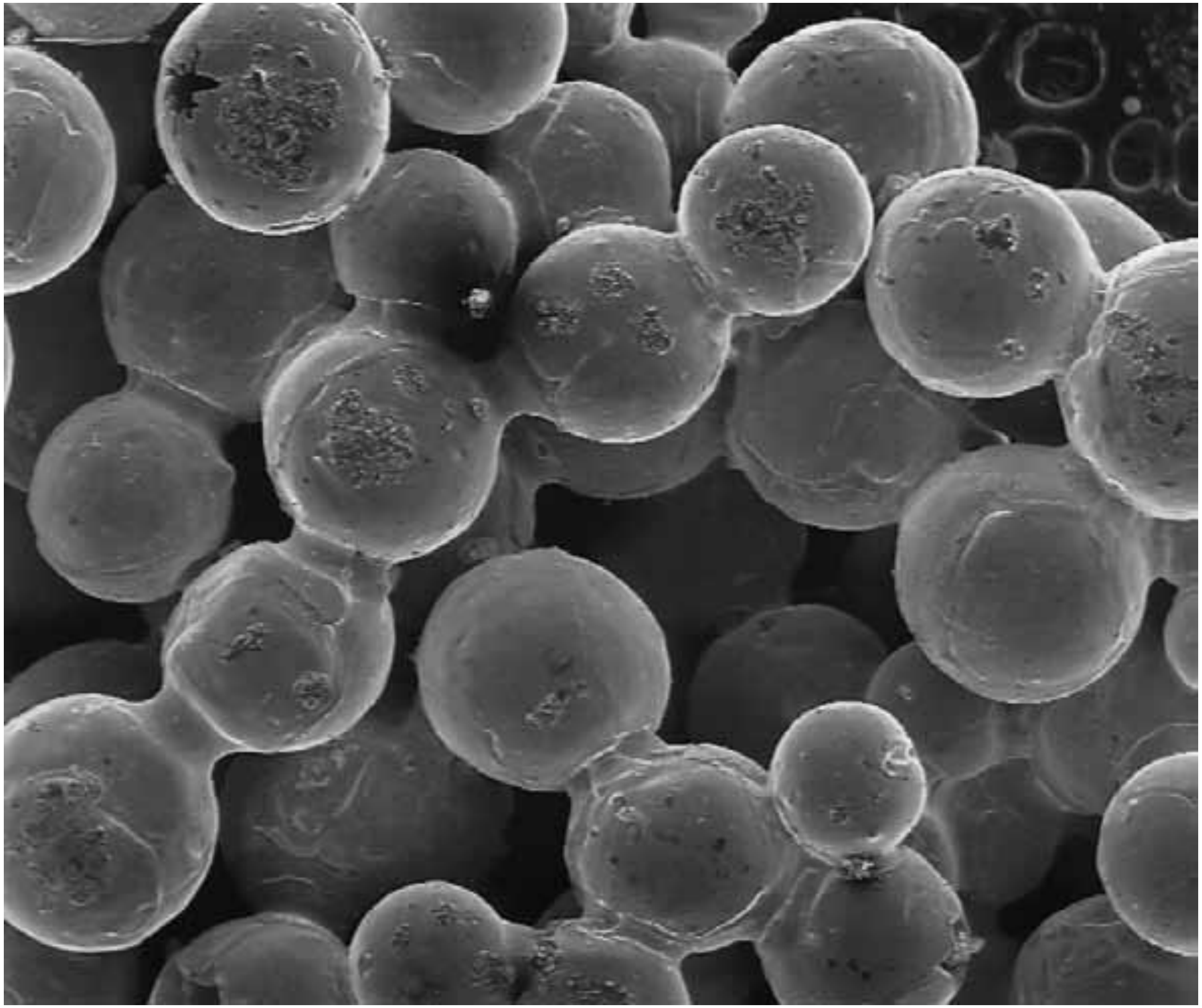


- <u>**Shrinkage always occurs:**</u>

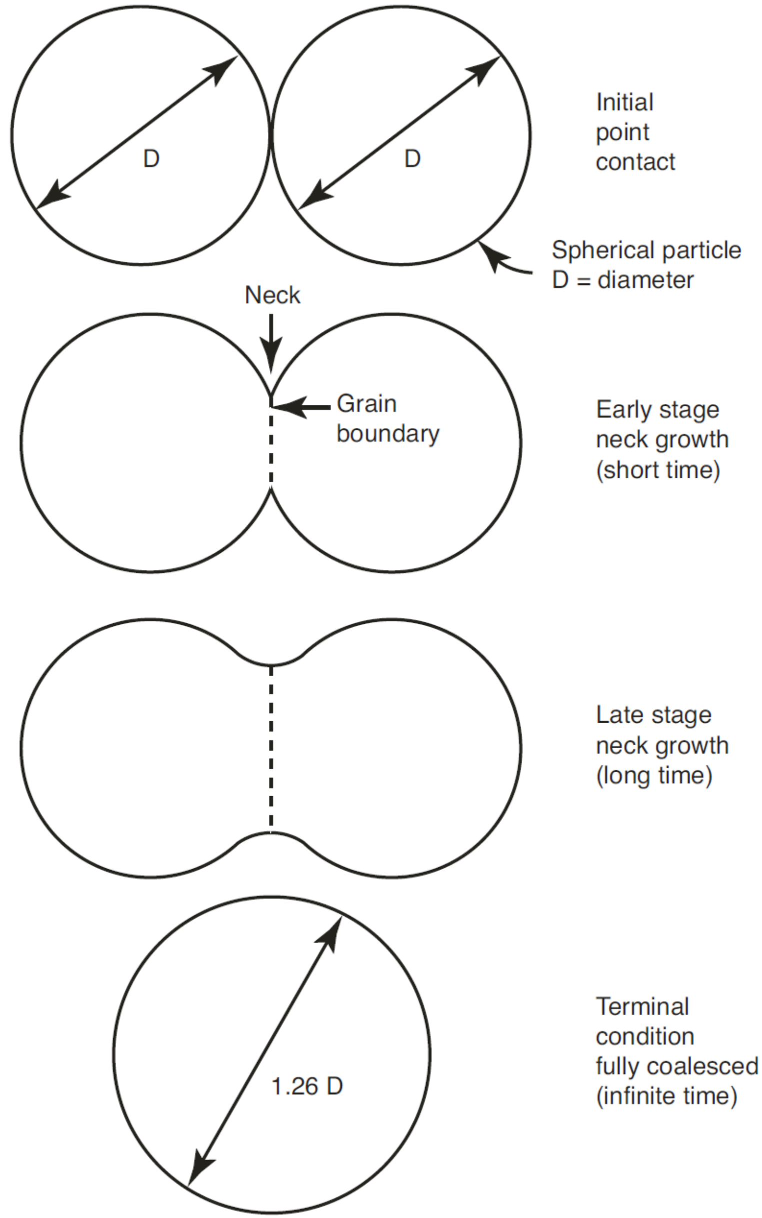
$$Vol\_shrinkage = \frac{V_{sintered}}{V_{green}} = \frac{\rho_{green}}{\rho_{sintered}}$$

$$Linear\_shrinkage = \left(\frac{\rho_{green}}{\rho_{sintered}}\right)^{1/3}$$

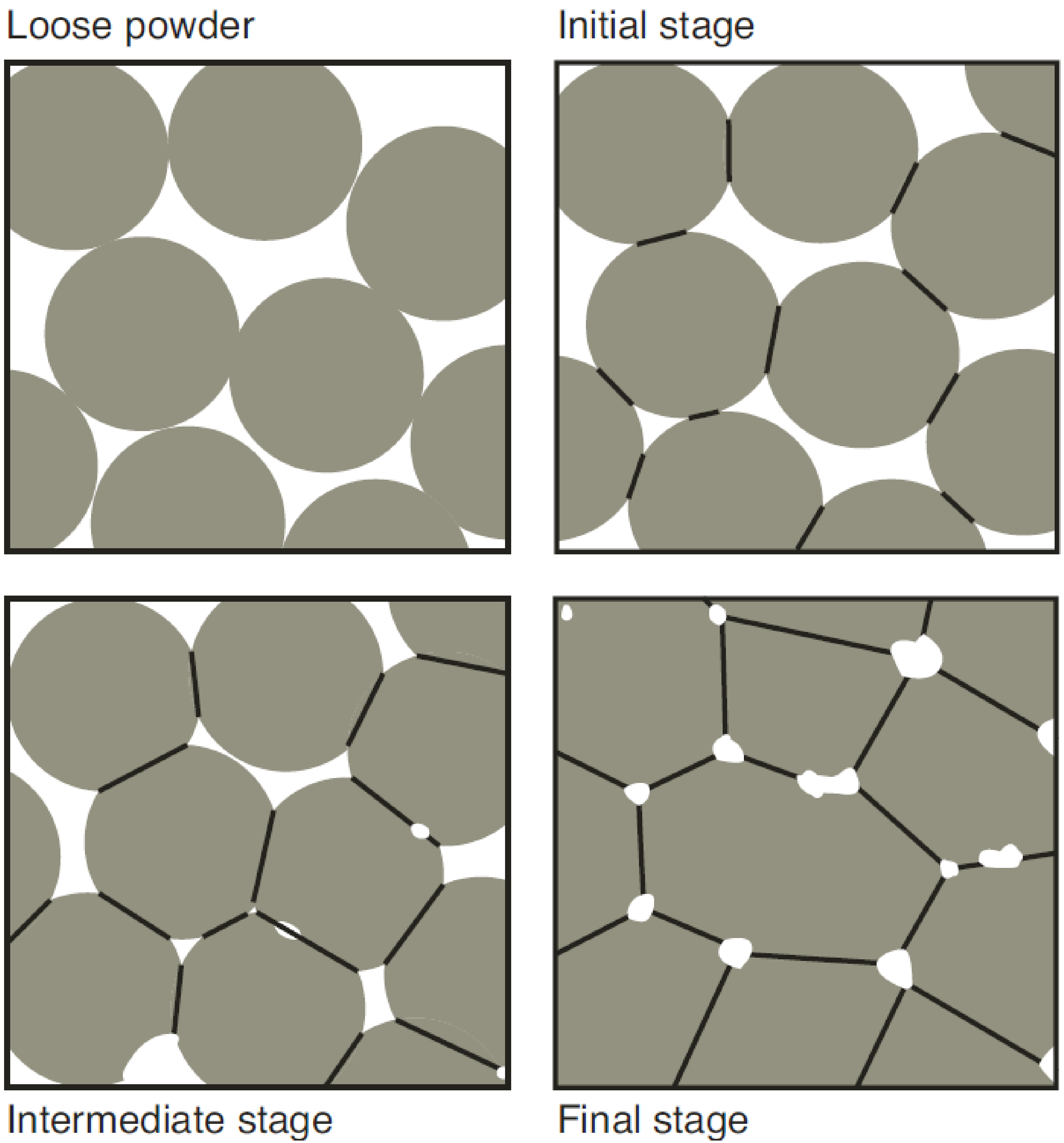




1.1 Scanning electron micrograph of the sintering neck formed between 26 μm bronze particles after sintering at 800 °C.



1.2 Two-sphere sintering model, where the two spheres grow a neck during sintering that grows to the point where the spheres fuse into a single sphere that is 1.26 times the diameter of the starting spheres.


Loose powder
Initial stage
Intermediate stage
Final stage

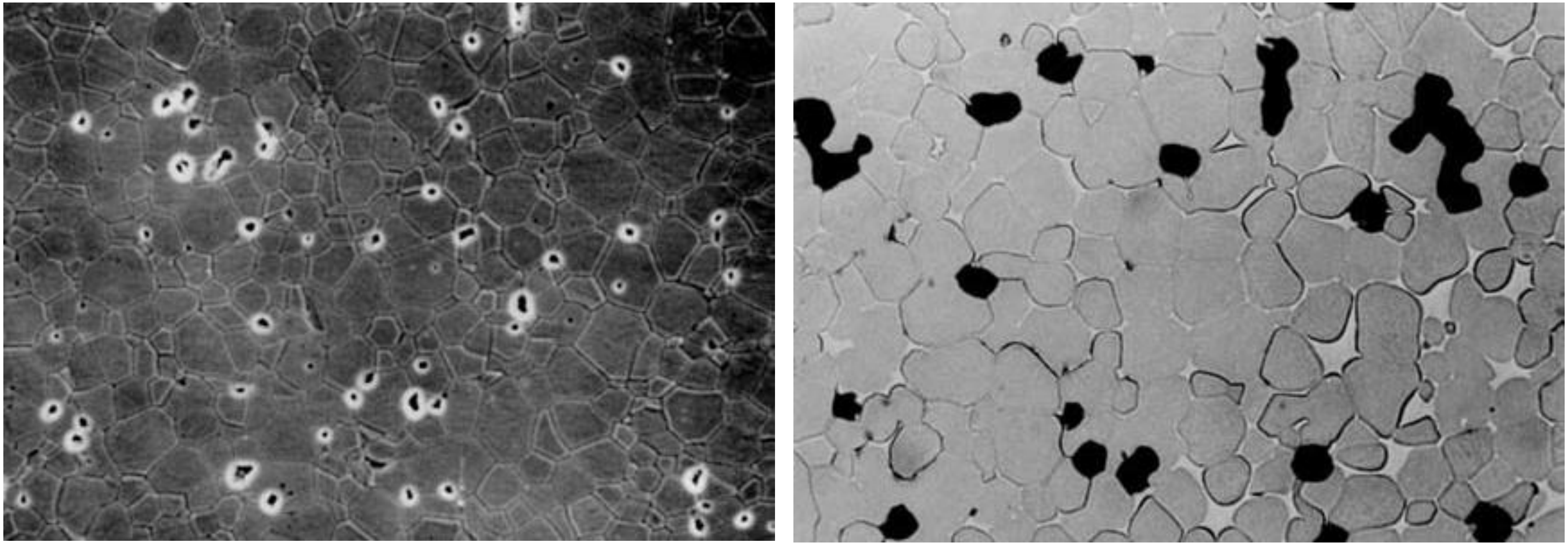


Figure 1.4. Typical microstructures observed during (a) solid state sintering (Al_2O_3) and (b) liquid phase sintering (98W-1Ni-1Fe(wt%)).

The functions of sintering atmosphere are :-

- It must prevent oxidation on the metal surface at the sintering temperature otherwise it would inhibit or interfere with the sintering process.
- It must avoid carburizing and decarburizing reactions and nitriding condition in certain metals.
- It must have the tendency of reduce surface films such as oxides on powder particles, If they are present, and remove or replace absorbed gases.
- It must not contaminate the metal powder compact at the sintering temperature.

The sintering furnaces atmosphere :-

- Reducing atmosphere.
- Neutral atmosphere.
- Oxidizing atmosphere.

1- Hydrogen :-

- Pure dry hydrogen is frequently used Sintering atmosphere especially in small furnaces and where very powerful reducing agent free from N_2 is required.
- It is wide applications in the industry in the sintering of steel, stainless steel, or any alloy containing over 1 % carbon or high cost, it has got the advantage of possessing a large sintering powder.

2- Dissociated or cracked Ammonia:-

- Dissociated ammonia is a mixture of 75 % hydrogen and 25% nitrogen by volume, which is equally effective, more economical and more convenient as regards the simplicity and reliability of operation than hydrogen atmosphere.
- For many purposes, it is possible to substitute this atmosphere for hydrogen.
- An added advantage is that it is free from oxygen and moisture and there is no danger of explosion.

3- Exothermic gas :-

- The most widely employed reducing sintering atmosphere is produced by the combustion of fuel gases such as paraffin, methane, butane, propane, natural gas, coal gas or coke – oven gas with premixed air in certain ratios.
- Burning occurs in an electrically heated or gas fired chamber filled with catalysts.
- The gas contains various amount of hydrogen, carbon monoxide, methane, carbon dioxide, nitrogen and water vapors.
- This gas may be reducing, carburizing, inert, decarburizing or even oxidizing depending upon its composition.

4- Endothermic gas :-

it is produced in the same way as the exothermic type protective atmosphere except that a mixture of hydrocarbon gas and air (low air – gas ratio) is heated over catalyst externally by gas or electricity for cracking the richer mixture or supporting the reaction.

5- Argon & Helium Inert gases:-

- Particularly argon and helium, are used to limited extent, because of their relatively high cost and lack of reducing potential.
- They are used advantageously for sintering of most reactive metals due to their inertness.

خواص وانواع اوساط التلبيد المستعملة فى ميتالورجيا المساحيق

اسم الوسط	التركيب الكيميائي	طريقة التحضير	مجال الإستعمال
إيدروجين تقنى (تجارى)	H^2 % 100 (شوائب من بخار الماء والأكسجين)	التحليل الكهربائي للمحاليل المائية	وسط حائل جامع ومختزل قوى ، عند تلبيد السبائك الصلدة والسبائك الصامدة للحرارة والسبائك ذات الخواص الفيزيائية الخاصة
النشادر المتحلل	75 % H^2 + 25 % نتروجين	تفكك (تحلل) النشادر عند درجة حرارة 700 – 750 °م	بديل الايدروجين يستعمل عند تلبيد كل أنواع المواد بإستثناء المواد الصعبة الانصهار والمعادن التي تمتص النتروجين عند درجات حرارة التلبيد .
الاكزوغاز	14 – 17 % H^2 + 10 % CO + 4 – 5 % CO^2 + 1 % CH4 والباقي نتروجين	احتراق مخلوط الغاز الطبيعي أو البروبان مع الهواء دون أعطاء أية حرارة خارجية	أرخص الأوساط الحائلة ويستعمل عند تلبيد مواد السراميك الفلزي التي أساسها الحديد والنحاس والفضة .. الخ
الاندوغاز	30 – 40 % H^2 + 20 – 25 % CO + صفر – 3 % CO^2 + صفر – 1 % CH4 والباقى نتروجين	احتراق مخلوط الغاز الطبيعي أو البروبان مع الهواء مع التسخين الخارجي	يستعمل عند تلبيد مواد السراميك الفلزي التي أساسها الحديد والتي تحتوى على كربون بنسب عالية ومتوسطة ، والمعادن غير الحديدية .. الخ
الغاز المحول	75 – 76 % H^2 +22 – 23 % CO +1 – 2 % CO^2 + 1.5 % H^2O + صفر – 1 % N^2 + 0.5 % CH4	تحويل (Conversion) الغاز الطبيعي مع بخار الماء عند درجة حرارة 1100 °م مع وجود حفارات (Catalyst)	يستعمل عند تلبيد قطع السراميك الفلزي التي أساسها الحديد والنحاس والسبائك الصلدة .. الخ
النتروجين التقني (التجاري)	95 % ازوت + مخلوط الاكسجين وبخار الماء وغير ذلك	من الهواء	عند تلبيد المواد التى أساسها الاتحادات غير المعدنية ... الخ

Optional Operations

Repressing		
Coining	All	Densification, modify surface shape (coining), dimensional control
Sizing	All	Dimensional control
Impregnation		
Oil	Bearings	Make bearings self-lubricating
Resin	Structural	Improve machinability. Prepare surface for plating with other metals. Seal parts gas or liquid tight. Provide lubrication.
Infiltration	Ferrous Structural	Improve strength; seal parts gas or liquid tight. Prepare surface for plating with other metals. Improve ductility and machinability.
Heat Treating		
Quench and Temper	Ferrous Structural	Improve strength and hardness.
Steam Treat	Ferrous	Make surface hard and wear resistant. Improve corrosion resistance and seal porosity.
Machining		
Drill and Tap	All	To install set screws or assembly fasteners.
Turning	All	Machine to exact tolerances. Form undercuts or features not possible with compaction tooling.
Milling	All	Form undercuts or slots.
Grinding	All	Remove stock; make faces flat and parrallel; improve surface finish and dimensional tolerances.

Optional Operations

Finishing

Deburring	All	Remove sharp edges related to punch and die tooling.
Burnishing	Ferrous Structural	Ball size, roller burnish for size control and surface finish
Coating Oil Dip	Ferrous	Corrosion resistance.
Copper, Nickel, Cadmium, Zinc, Chromium Plating	Ferrous	Corrosion resistance; appearance.
Welding	Ferrous, 6.8 g/cm^3 min. density	Make assemblies from two or more parts.
Black Oxide	Ferrous, resin impregnated	Corrosion resistance, paint base.
Mechanical Surface Treatments: Glass Beading Wire Brush Sanding, Tumbling/ Vibratory Finishing	All	Clean/improve surfaces.
Shot Peening	Ferrous Structural, Forgings	Improve surface fatigue life.

Design Considerations

- Dimensional accuracy depends upon:
  - Control of powder composition
  - Size of dimension
  - Control of powder fed to the tools with each stroke
  - Control of press and tooling variables
  - Control of sintering variables

MPIF
Reference Tolerance Guide

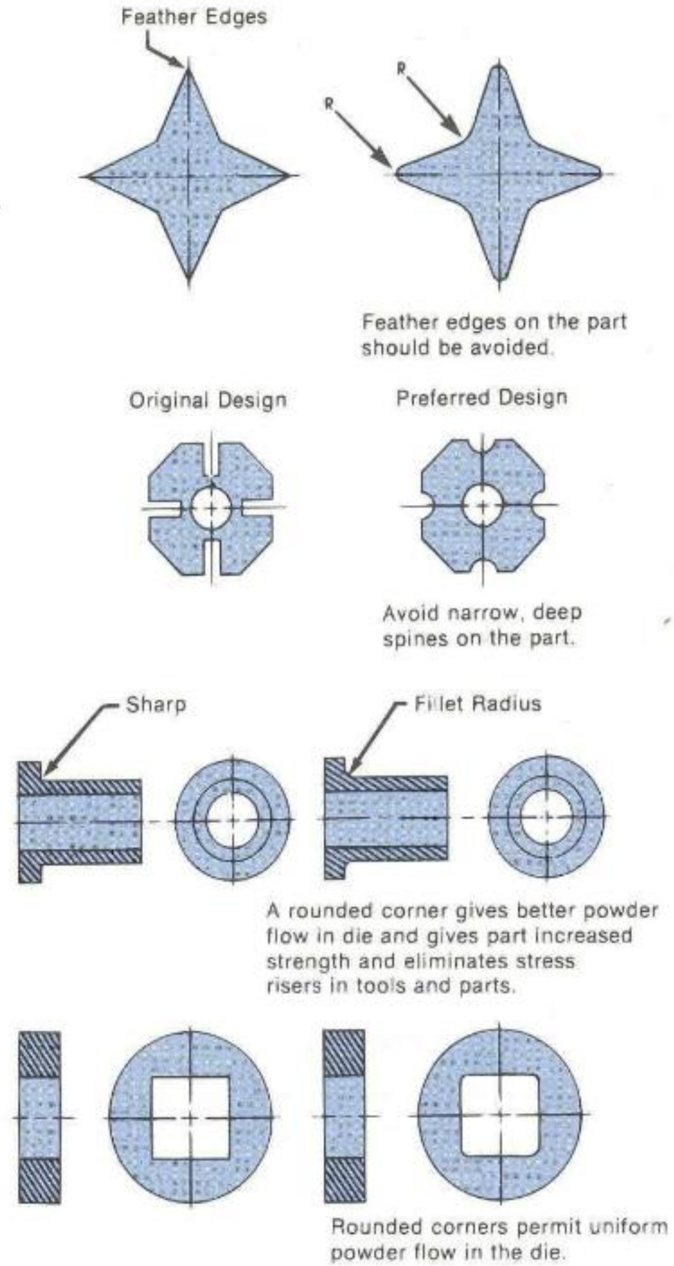
Typical tolerances for ferrous P/M components up to 2.00 inches in dimension

Tolerances, inch/inch

Characteristic	Practical	Possible
Length	±.005	±.003
Inside Diameter	±.002	±.001
Outside Diameter	±.002	±.001
Concentricity	.006	.004
Flatness on Ends	±.002	±.001
Parallel of Ends	±.0015	±.001

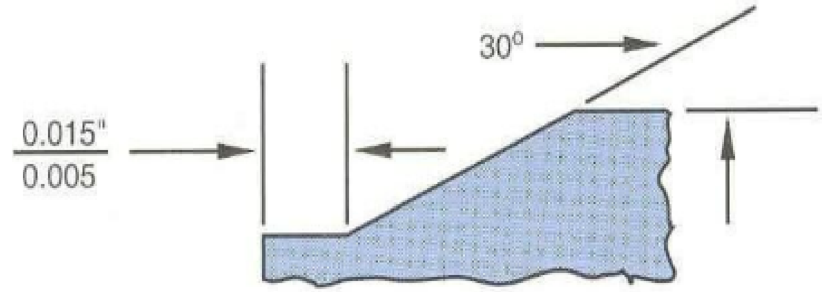
Design Details

- Fillets and Radii
  - Tooling with such fillets are more economical, longer lasting
  - Parts made with generous fillets are more economical
  - Parts made with fillets have greater structural integrity

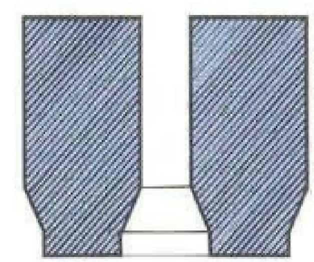


Design Details

- Holes in the pressing direction can be round, D-Shaped, keyways or splines
- Wall thickness is all important; walls thinner than .060 inches are avoided.
- Flatness depends on part thickness and surface area.
- Thin parts tend to distort more than thick parts
- Chamfers rather than radii are necessary on part edges



- Chamfers are preferred on part edges.



- Chamfers in clearance.