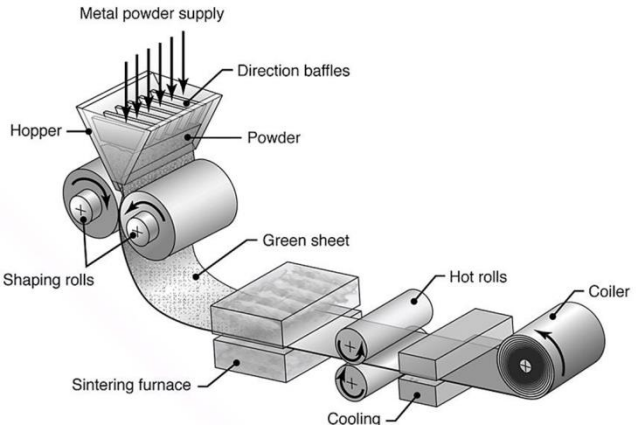
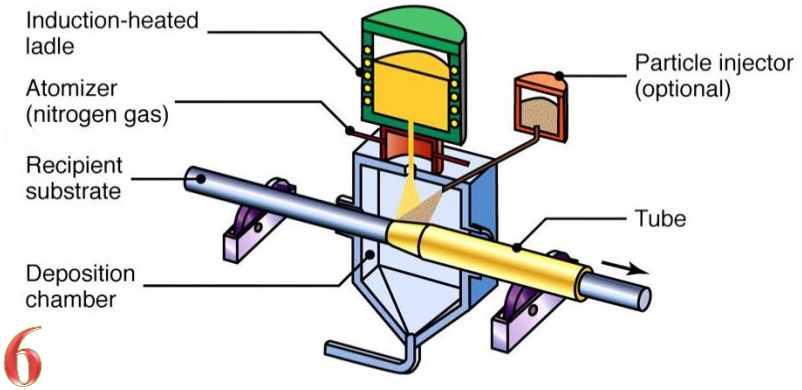
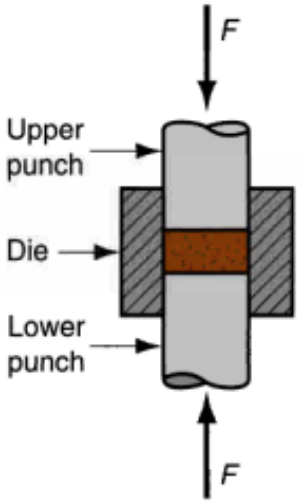


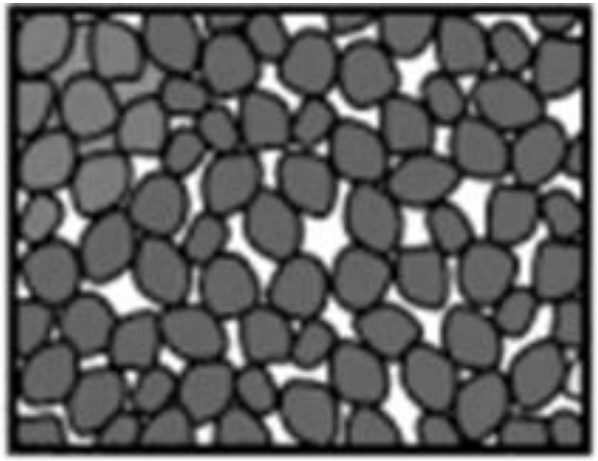


Lecture # 6

POWDER METALLURGY

Compaction





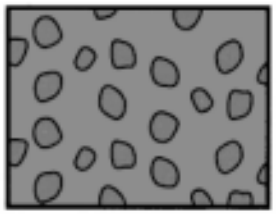
Dr. Mohammed Gamil

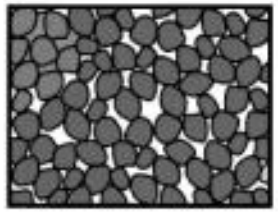
PM Sequence

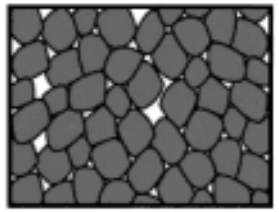
After the metallic powders have been produced, the conventional PM sequence consists of three steps:

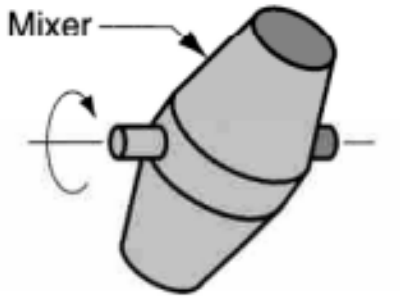
1. Blending and mixing of the powders
2. Compaction - pressing into desired part shape
3. Sintering - heating to a temperature below the melting point to cause solid-state bonding of particles and strengthening of part

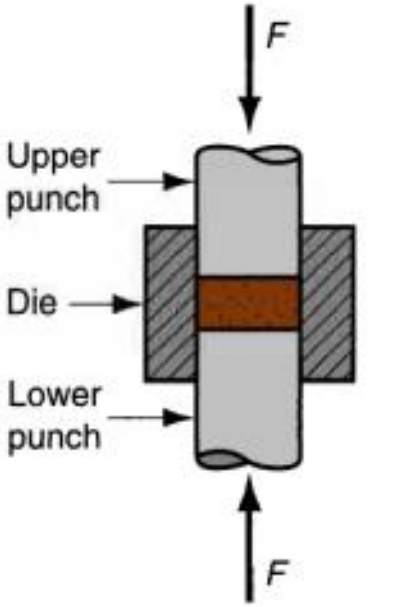
PM Sequence (Cont.)

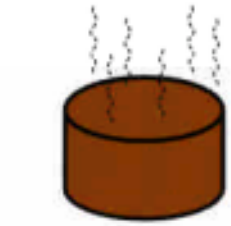












Mixing

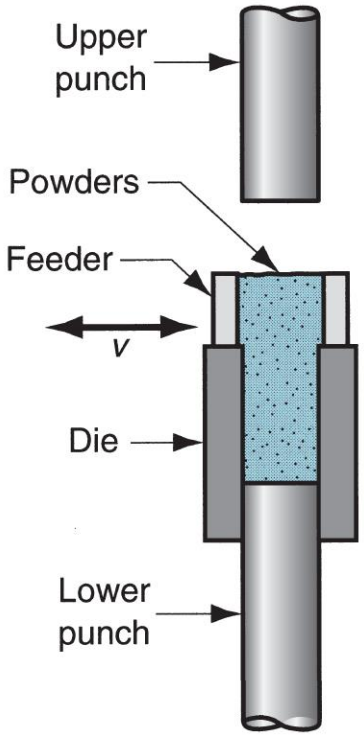
Compaction

Sintering

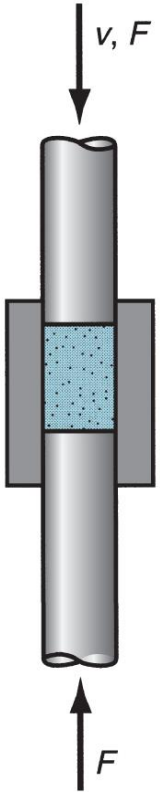
Compaction

- Application of high pressure to the powders to form them into the required shape.
- The conventional compaction method is pressing, in which opposing punches squeeze the powders contained in a die.
- The workpart after pressing is called a green compact, the word green meaning not yet fully processed.
- The green strength of the part when pressed is adequate for handling but far less than after sintering

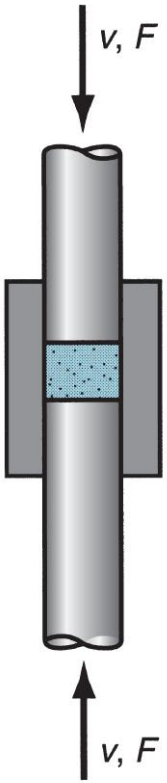
Compaction Cycle



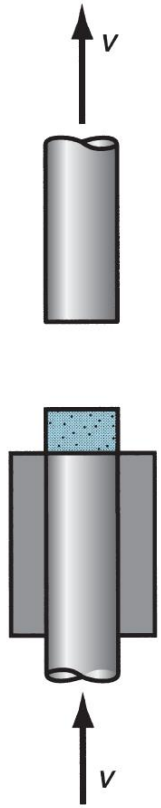
Filling die cavity with powder by automatic feeder



Initial position

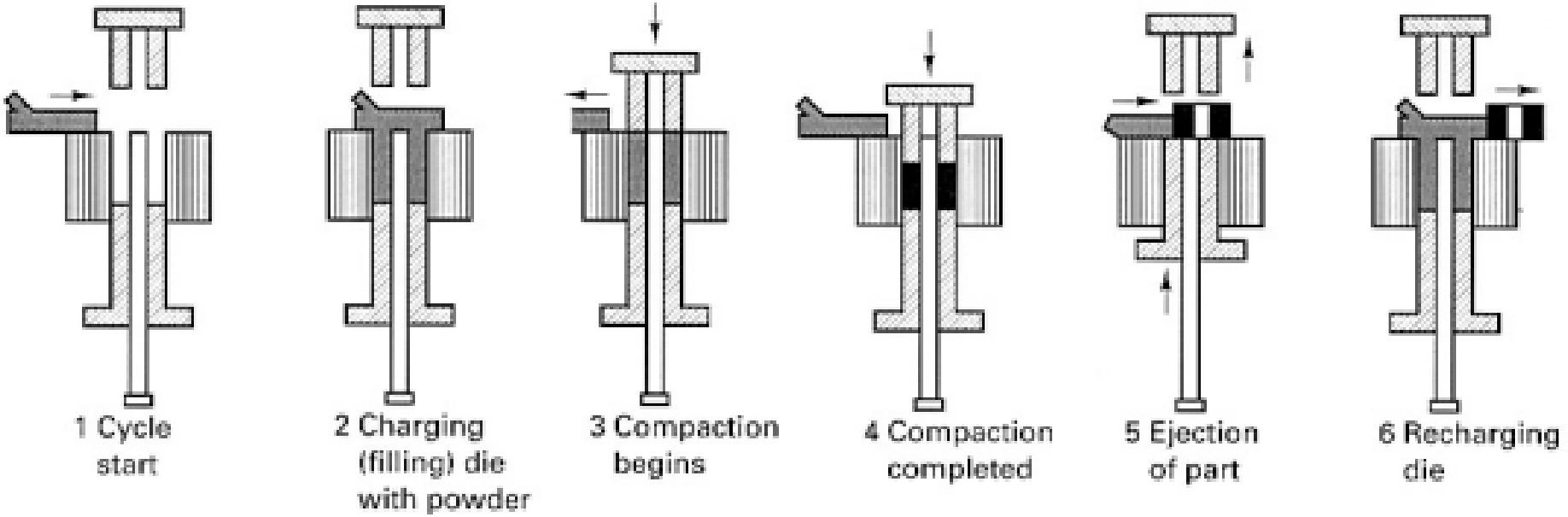


Final positions of upper and lower punches during pressing



Ejection of part

Compaction Cycle (Cont.)



Compacting Pressures for Various Powders

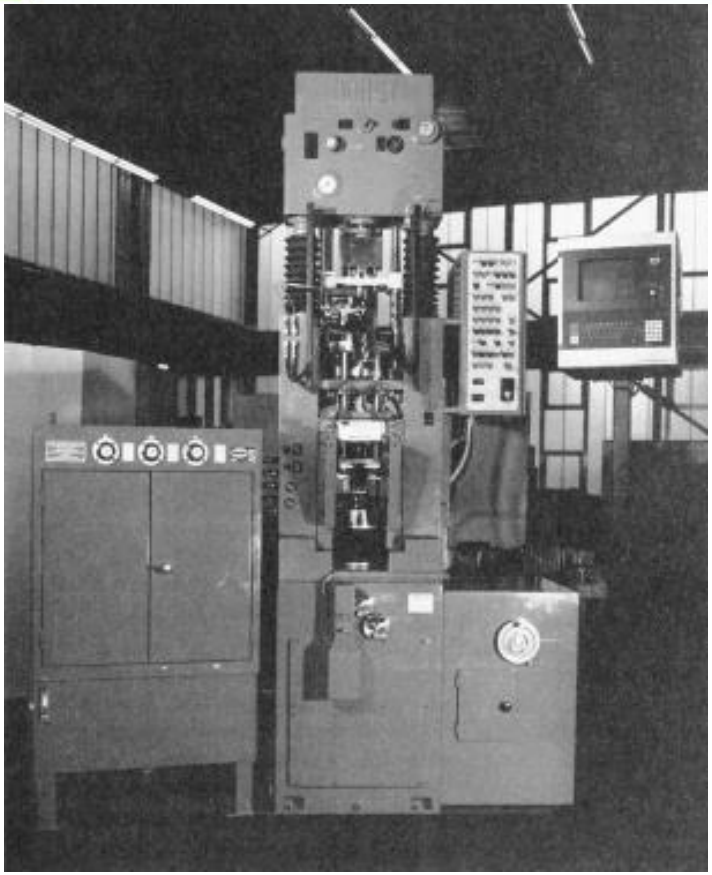
Metal	Pressure (MPa)
Aluminum	70-275
Brass	400-700
Bronze	200-275
Iron	350-800
Tantalum	70-140
Tungsten	70-140
Other materials	
Aluminum oxide	110-140
Carbon	140-165
Cemented carbides	140-400
Ferrites	110-165

Compaction Presses

- Compacting is done with

1. Mechanical presses and rigid tools.
2. Hydraulic press
3. pneumatic press
4. Cold isostatic press
5. Hot isostatic press

Compaction Presses (Cont.)

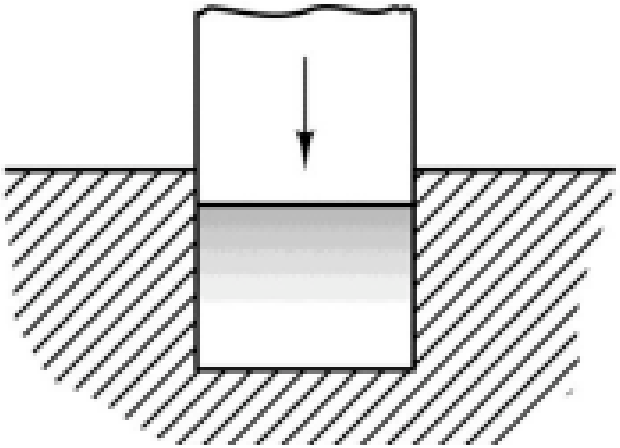


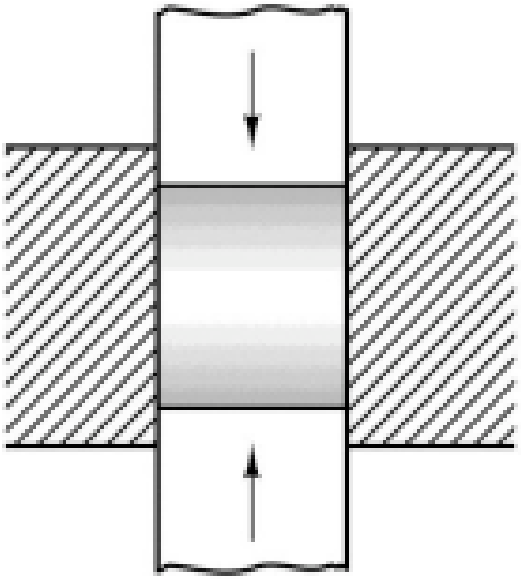
50-ton hydraulic press for compacting metal powder.

825-ton mechanical press for compacting metal powder.

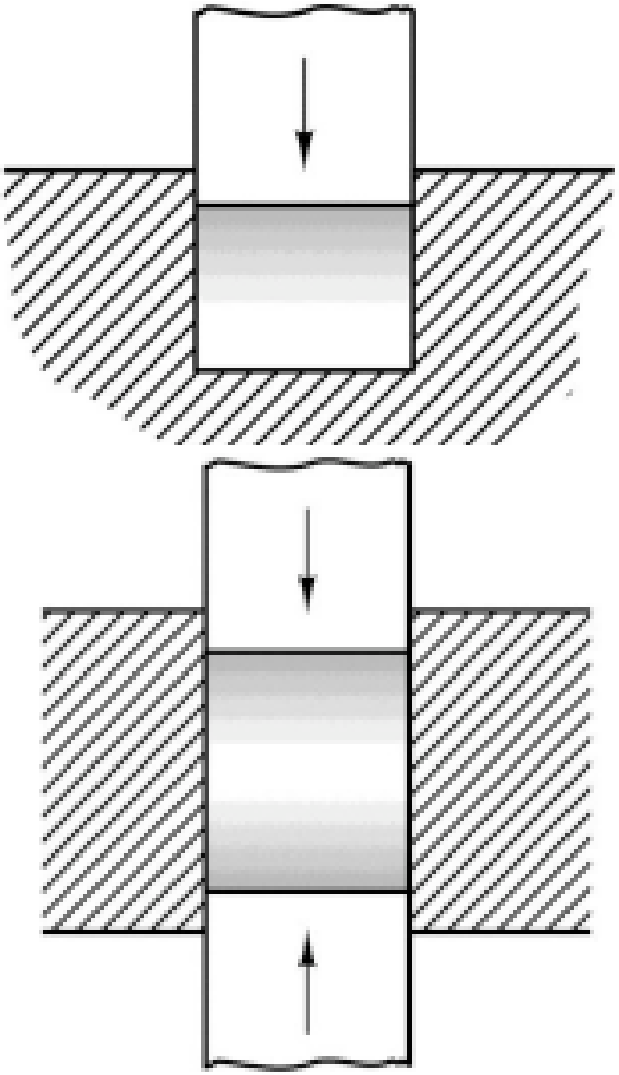
Compaction and Density

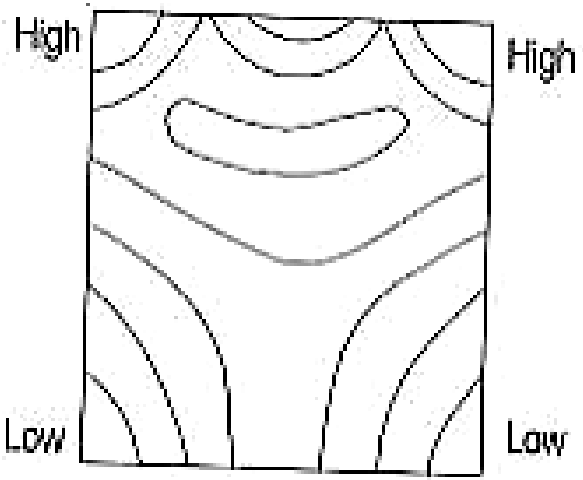
- When the pressure is applied by only one punch, the maximum density occurs right below the punch surface and decreases away from the punch.
- For complex shapes, multiple punches should be used

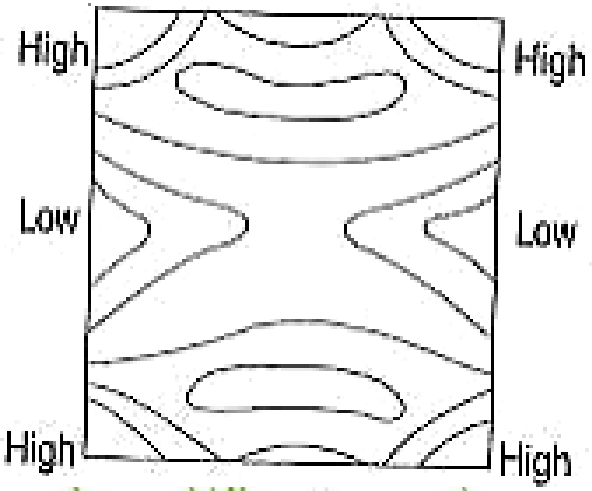




Pressure Distribution





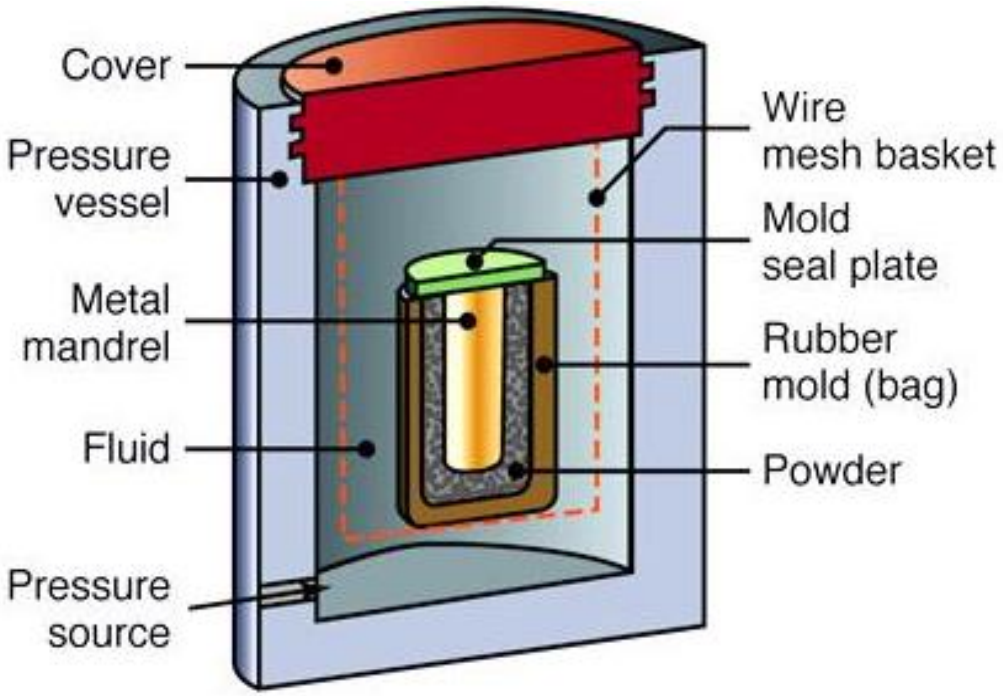


Complex Compacting

- If an extremely complex shape is desired, the powder may be encapsulated in a flexible mold, which is then immersed in a pressurized gas or liquid.
- Process is known as isostatic compaction.
- In warm compaction, the powder is heated prior to pressing.
- The amount of lubricant can be increased in the powder to reduce friction.

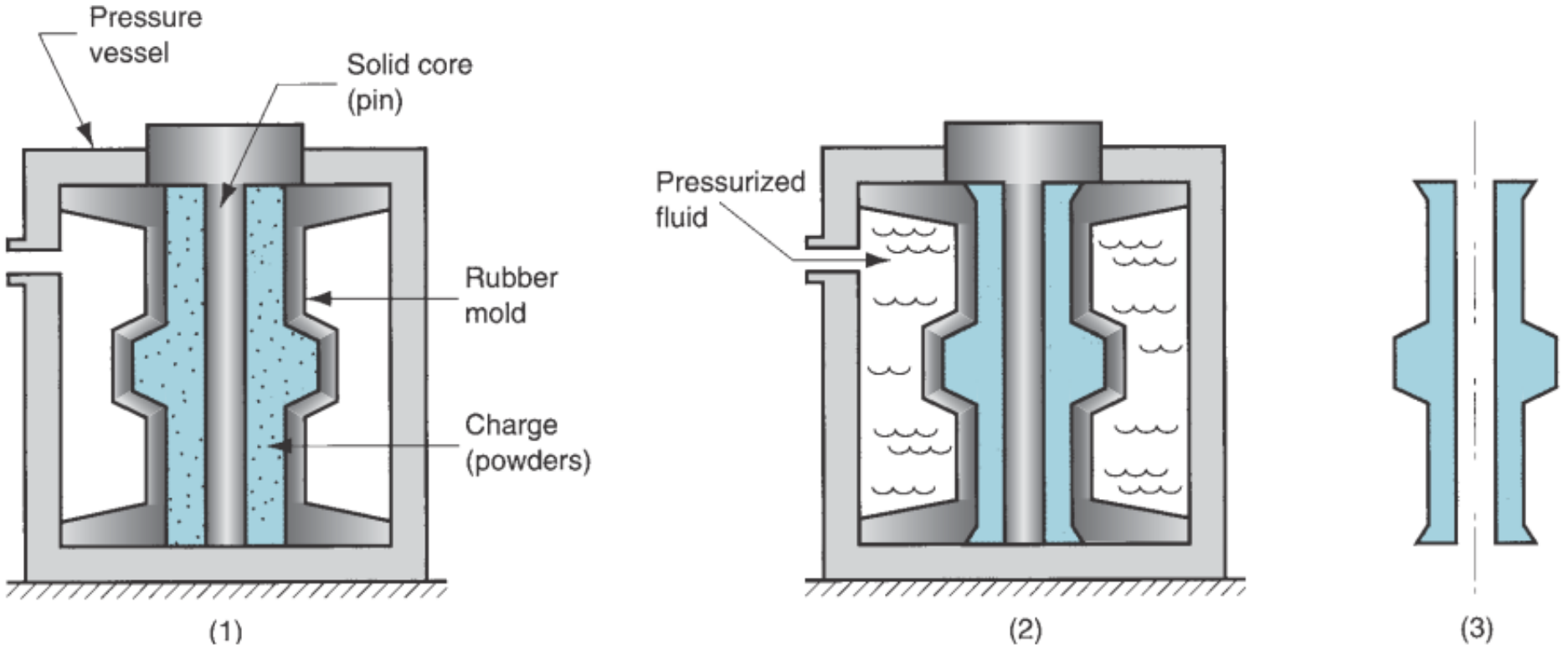
Cold Isostatic Pressing

Pressure is applied from all directions against the powder.



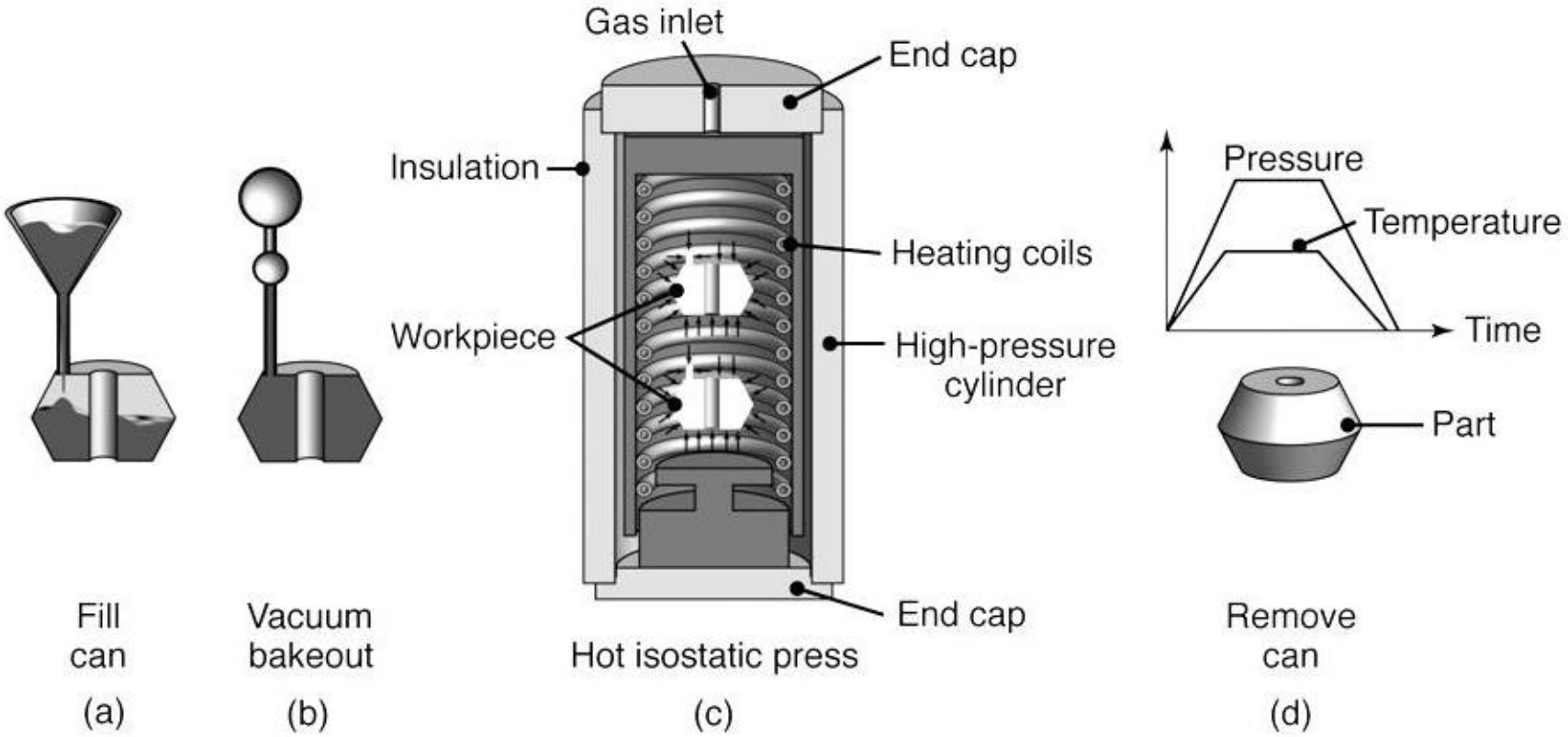
Schematic diagram of cold isostatic pressing, as applied to forming a tube. The powder is enclosed in a flexible container around a solid-core rod. Pressure is applied isostatically to the assembly inside a high-pressure chamber.

Example on Cold Isostatic Pressing



Cold isostatic pressing: (1) powders are placed in the flexible mold; (2) hydrostatic pressure is applied against the mold to compact the powders; and (3) pressure is reduced and the part is removed.

Hot Isostatic Pressing

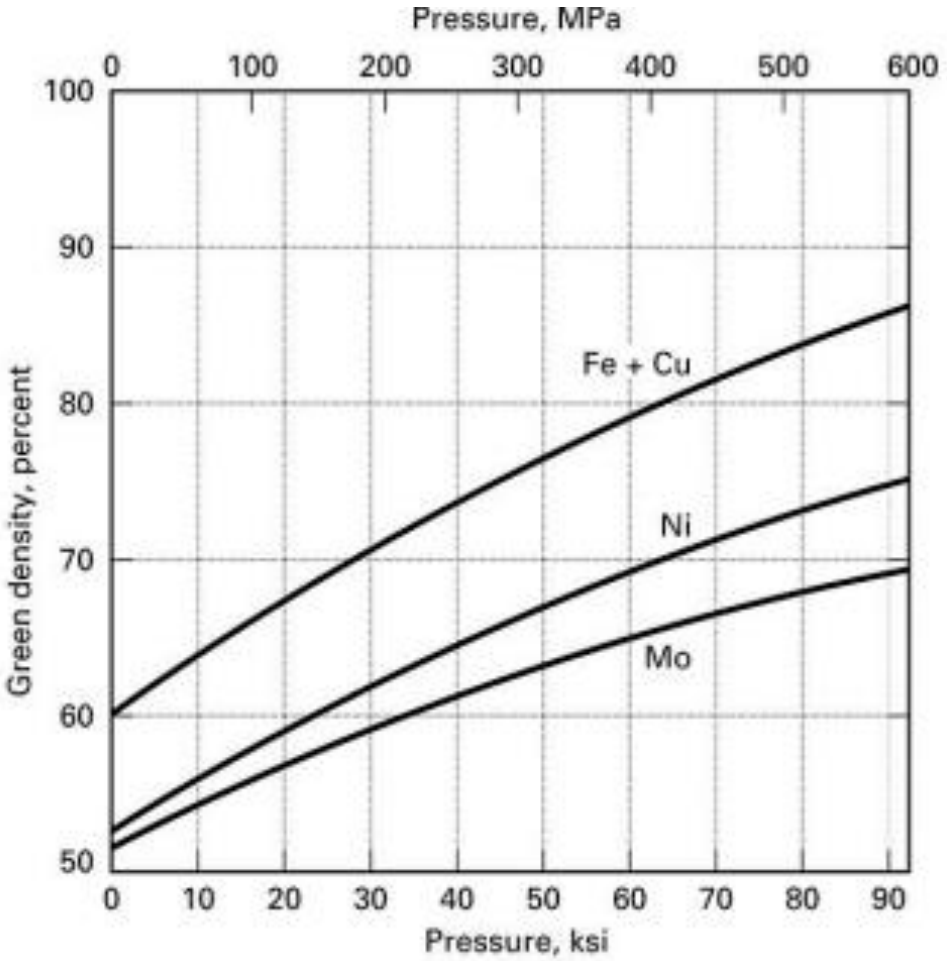


Schematic illustration of hot isostatic pressing. The pressure and temperature variation versus time are shown in the diagram

Hot Isostatic Pressing (Cont.)

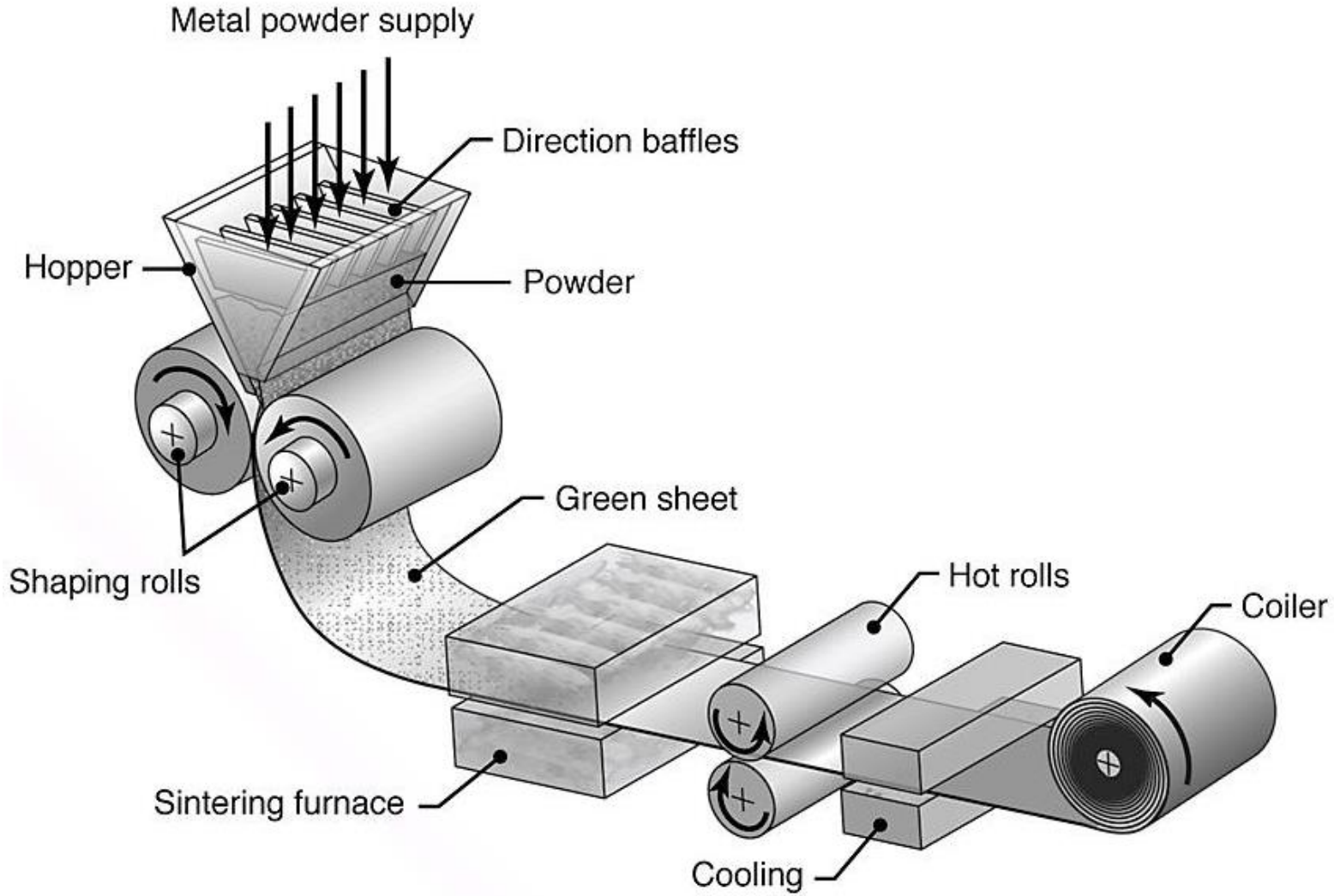
- Ideal method for consolidation of powders of nickel and cobalt base super alloys, tool steels, maraging steels, titanium alloys, refractory metal powders, cermets.It has got variety of applications including bonding of dissimilar materials, consolidation of plasma coatings, processing hard and soft magnetic materials.
- HIP is the application of pressure at elevated temperatures to obtain net or near net shape parts from metal, ceramic, cermet powders.
- HIP unit consists of a pressure vessel, high temperature furnace, pressurizing system, controls and auxiliary systems (material handling, vacuum pumps, metering pumps).
- The pressure vessel is made of low alloy steel. Its function is to heat the powders while applying uniform gas pressure on all the sides. Furnaces are of radiation or convection type heating furnaces with graphite or molybdenum heating elements. Nichrome is also used. The furnace heats the powder part, while pressurizing medium (a gas) is used to apply a high pressure during the process. Generally, argon, nitrogen, helium or even air is used as pressurizing medium.
- The pressurizing gas, usually argon, is let into the vessel and then a compressor is used to increase the pressure to the desired level. The furnace is then started and both temperature and pressure are increased to a required value.

Effect of Compaction on Strength



Effect of compacting pressure on green density (the density after compaction but before sintering). Separate curves are for several commercial powders.

Powder Rolling



Powder Rolling (cont.)

12” wide Ti-6Al-4V strip

Powder Rolling (cont.)

- This process involves feeding of powders between rolls to produce a coherent and brittle green strip. This green strip is then sintered & re-rolled to obtain a dense, finished product.
- Steps:
    1. Preparation of green strip
    2. Sintering
    3. Densification of sintered strip
    4. Final cold rolling and annealing

Parameters Affecting Powder Rolling

1. Roll gap
2. Roll diameter
3. Roll speed
4. Powder characteristics

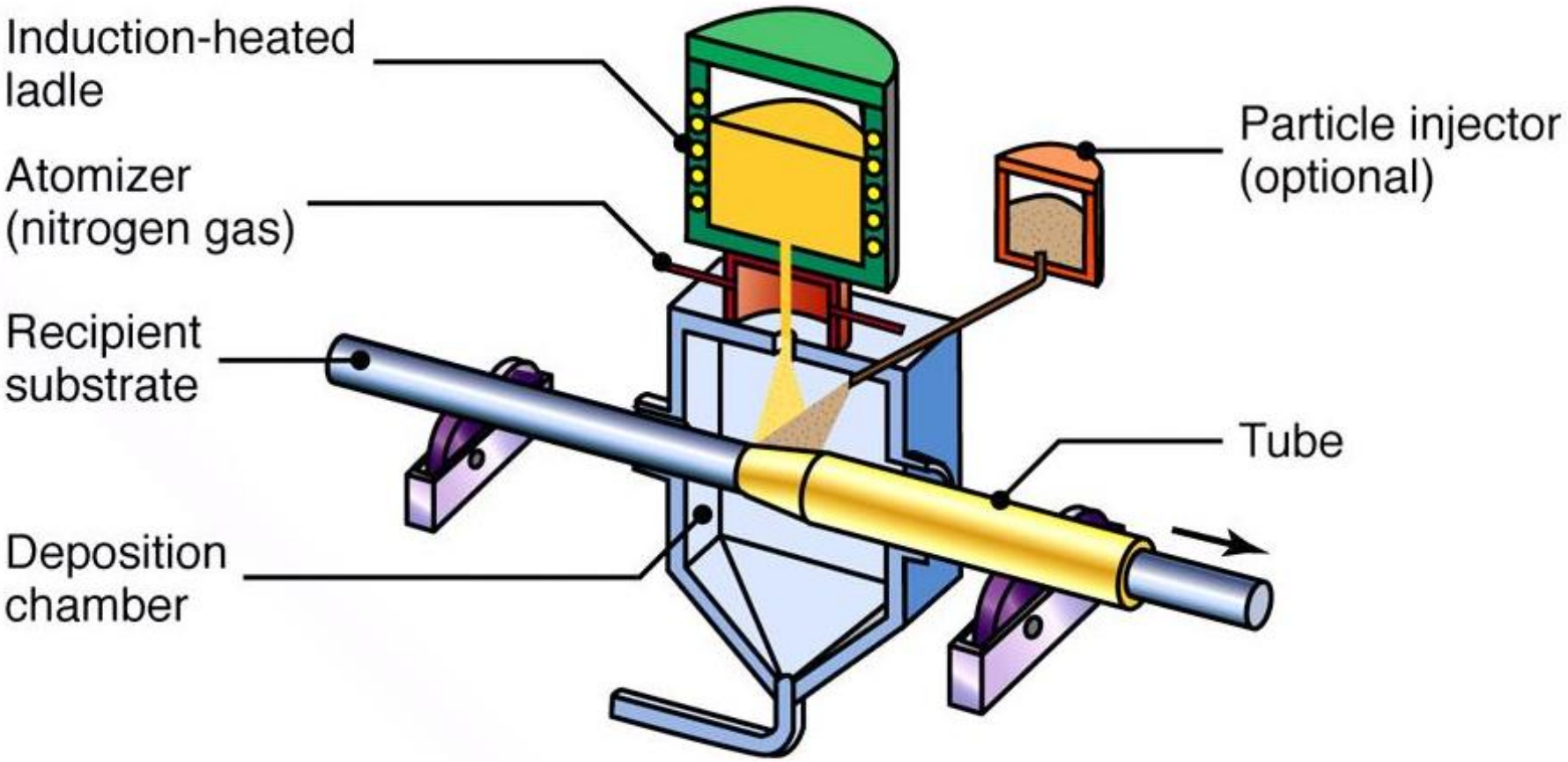
Parameters Affecting Powder Rolling (Cont.)

- Roll gap => large roll gap leads to decrease in green density; very small roll gap leads to edge cracking
- Roll diameter => increase in density and strength with increase in roll dia. for a given strip thickness
- Roll speed => Kept low, 0.3-0.5 m/s
- Powder => irregular powder with rough surfaces provide better strip density

Applications

- Nickel strips for coinage
- Nickel-iron strips for controlled expansion properties
- Cu-Ni-Sn alloys for electronic applications
- Porous nickel strip for alkaline batteries and fuel cell applications

Powder Spraying




Thank You!