Powder Metallurgy

Lecture By:
M K PODDAR
Asst. Professor
ME Dept., SIT Sitamarhi
Personal Web: https://ajourneywithtime.weebly.com/mfg-processes.html

Powder Metallurgy

- PM is a metal shaping process that creates near-net parts from powdered metal.
- Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape or form (compacting), and then heating the compressed material in a controlled atmosphere to bond the material (sintering).

The powder metallurgy process consists of four basic steps:

- Powder manufacture
- Powder blending
- Compacting
- Sintering

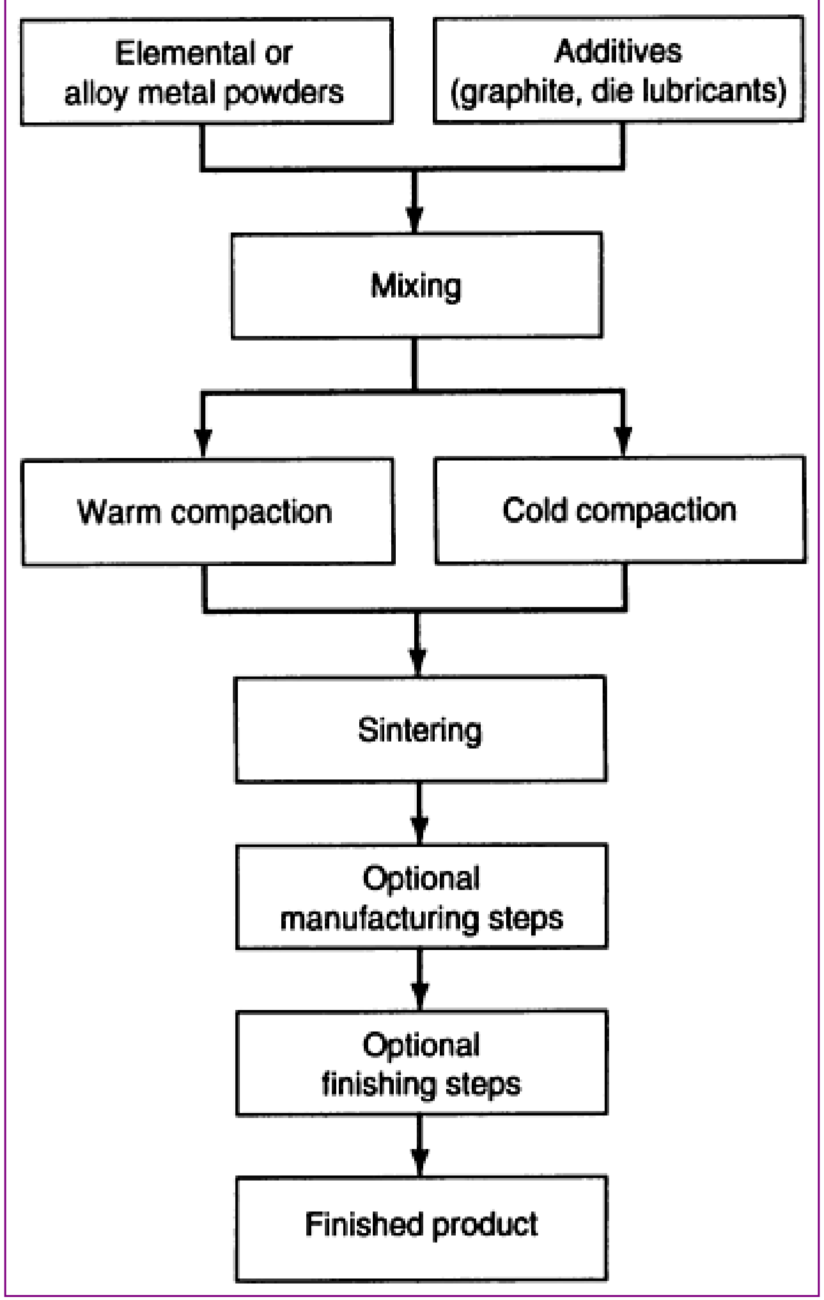
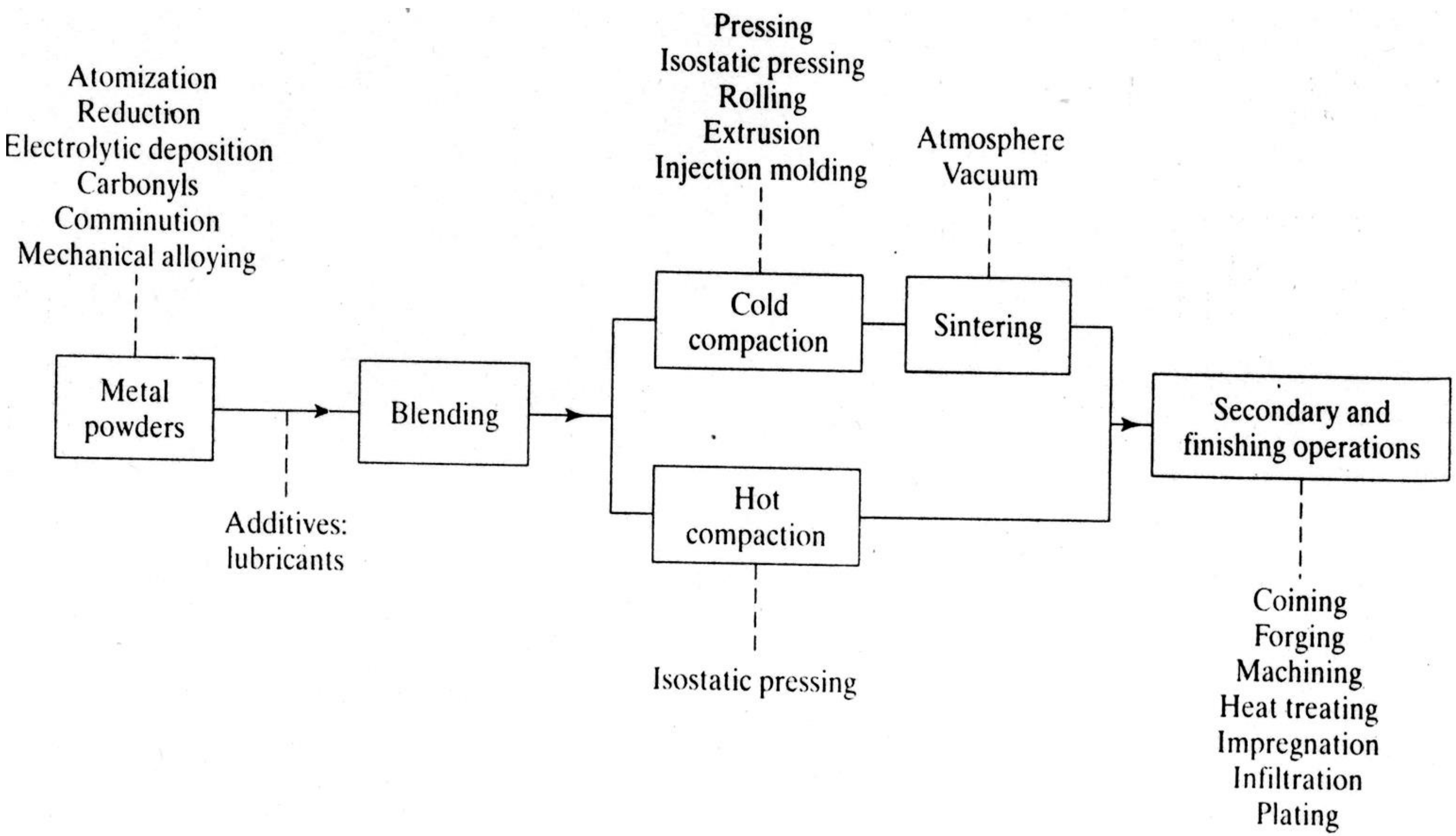


Figure: General steps in the P/M process

Powder Metallurgy Process

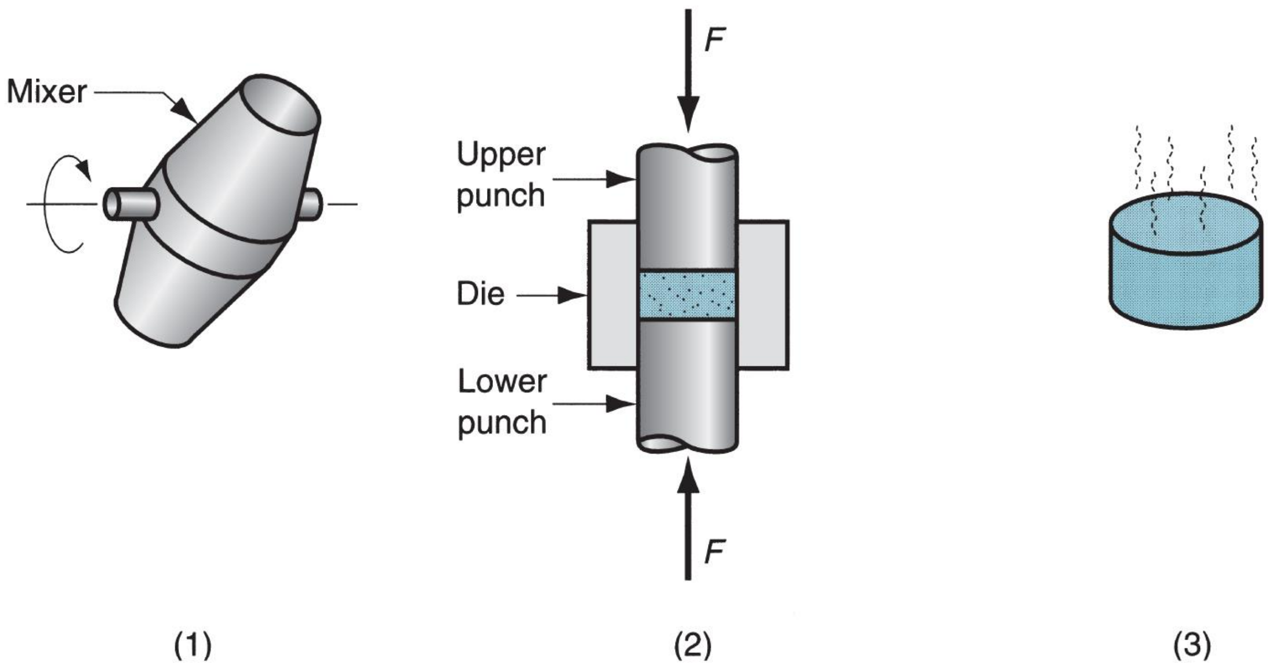


Basic Steps In Powder Metallurgy (P/M)

- Powder Production
- Blending or Mixing
- Compaction
- Sintering
- Finishing

Conventional PM Production Sequence

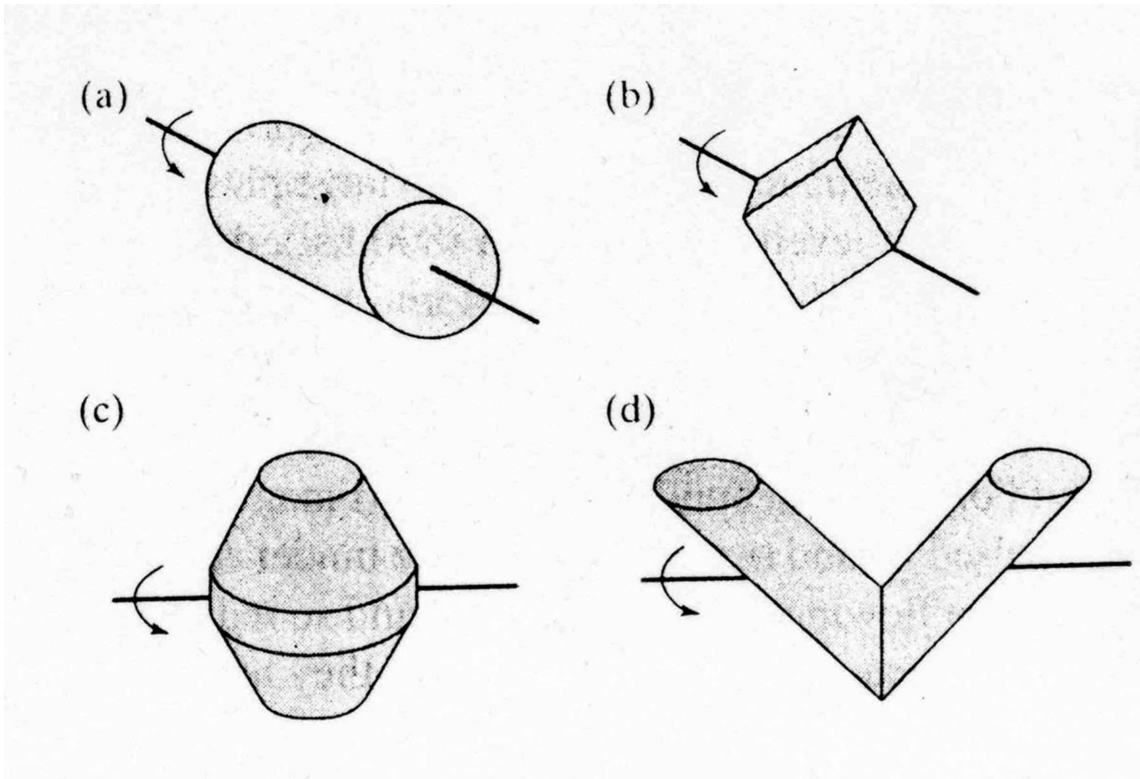
(1) Blending, (2) compacting, and (3) sintering



Blending and Mixing of Powders

- For successful results in compaction and sintering, the starting powders must be homogenized
- Powders of different metals and other materials may be mixed in order to impart special physical and mechanical properties through metallic alloying.
- Lubricants may be mixed to improve the powders' flow characteristics.
- Binders such as wax or thermoplastic polymers are added to improve green strength.

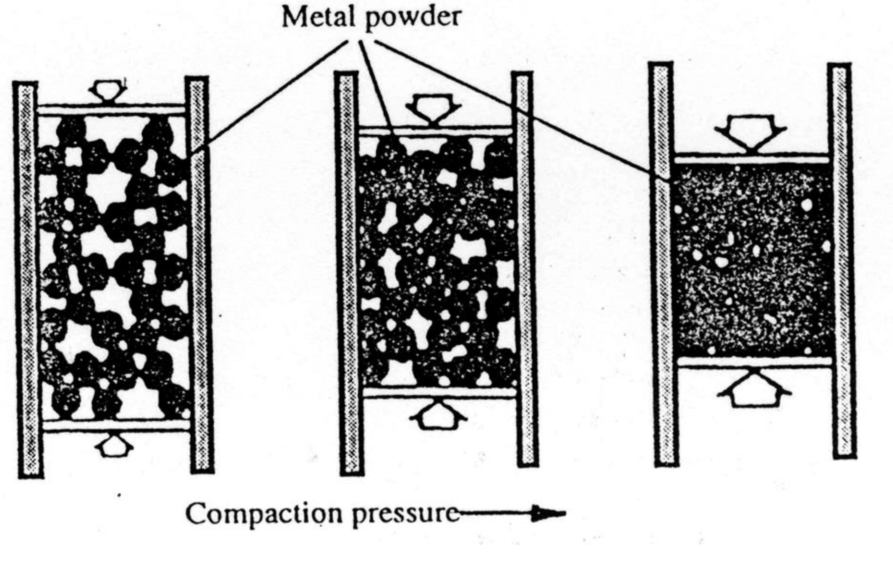
Blending



Some common equipment geometries used for blending powders
(a) Cylindrical, (b) rotating cube, (c) double cone, (d) twin shell

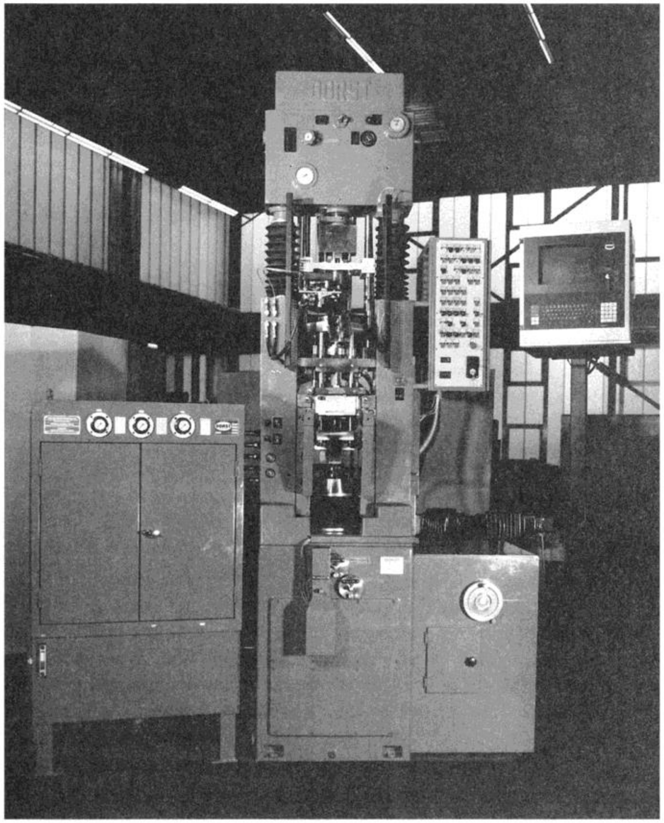
Compaction

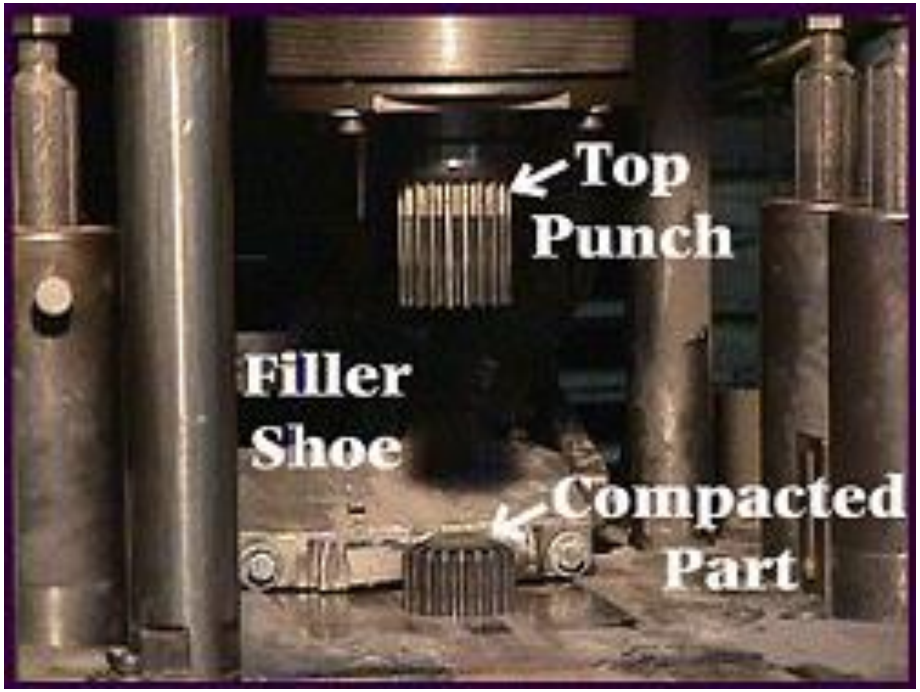
- Press powder into the desired shape and size in dies using a hydraulic or mechanical press.
- Conventional compaction method is *pressing*, in which opposing punches squeeze the powders contained in a die.
- The work part after pressing is called a *green compact*, the word green meaning not fully processed.
- Stages of metal powder compaction:



Press for Conventional Pressing in PM

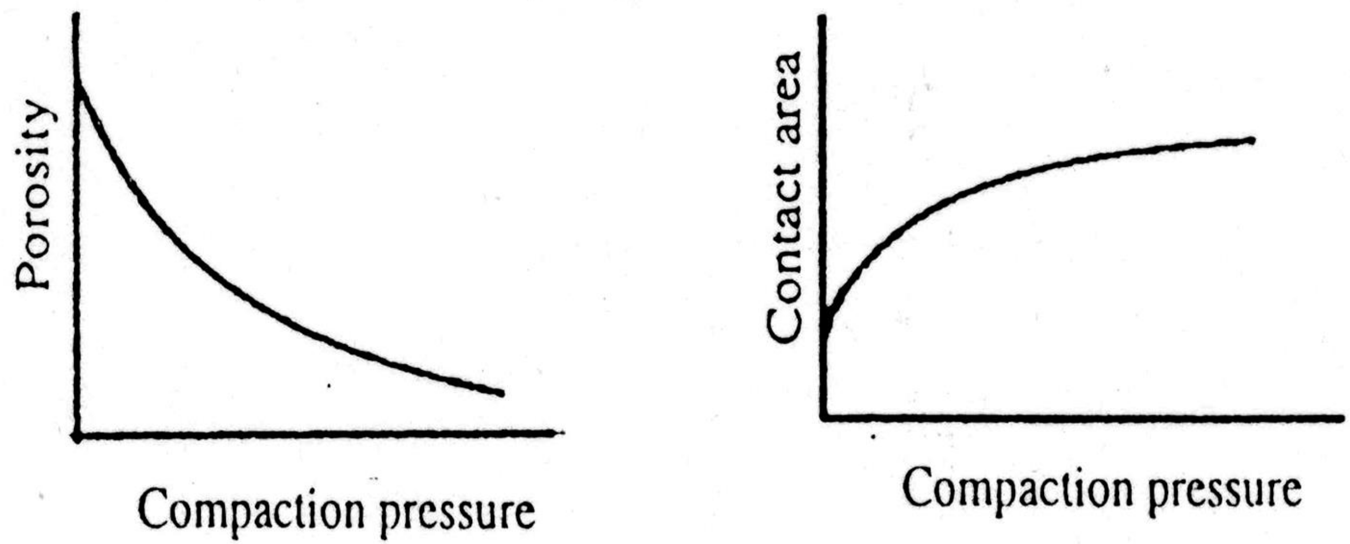
- 450 kN (50-ton) hydraulic press for compaction of PM parts (photo courtesy of Dorst America, Inc.).




Top
Punch
Filler
Shoe
Compacted
Part

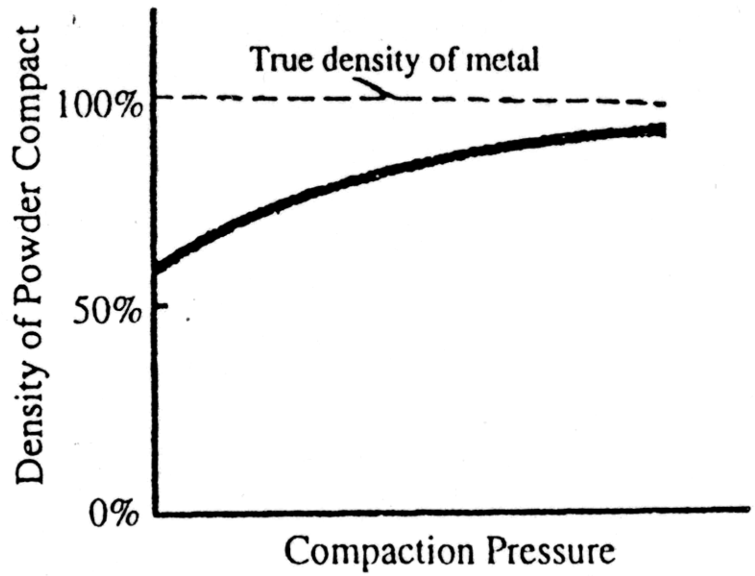

HYDRO-PAC

Compaction



- Increased compaction pressure
  - Provides better packing of particles and leads to ↓ porosity
  - ↑ localized deformation allowing new contacts to be formed between particles

Compaction



- At higher pressures, the green density approaches density of the bulk metal
- Pressed density greater than 90% of the bulk density is difficult to obtain
- Compaction pressure used depends on desired density

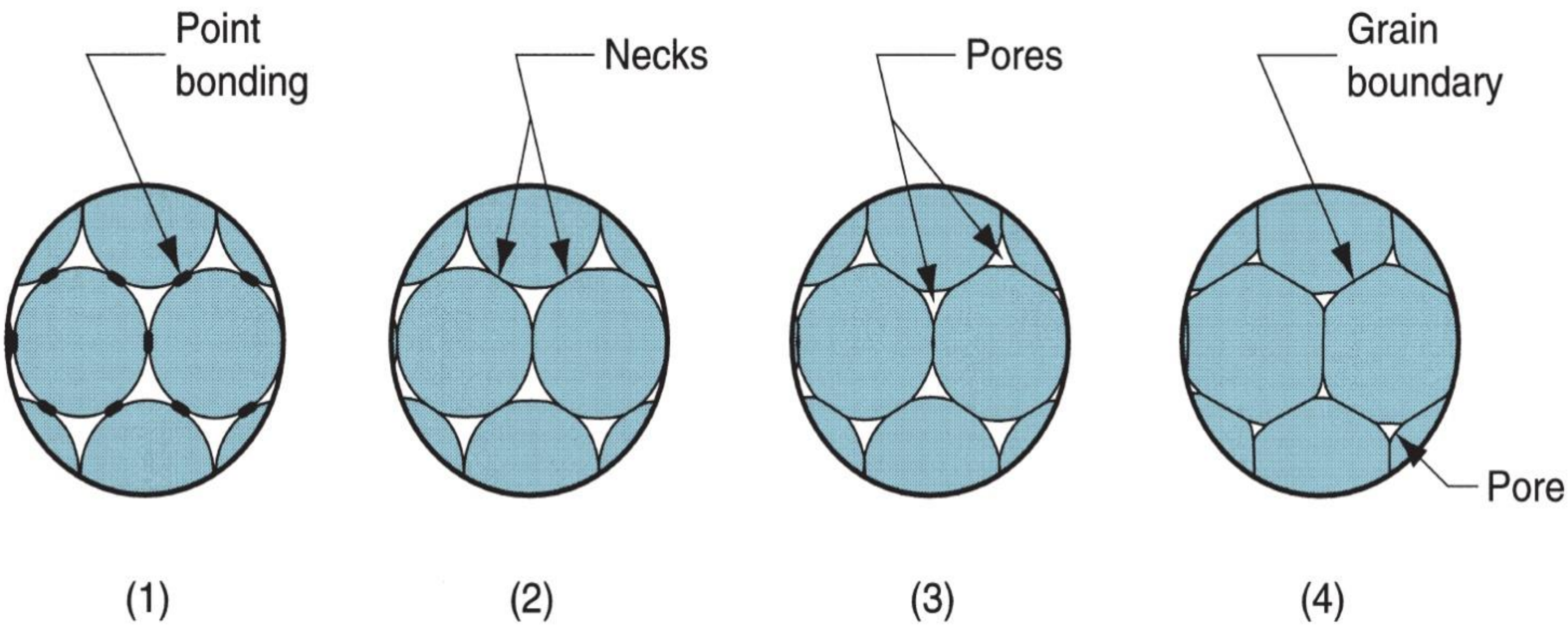
Sintering

- In green condition of compact shape possess low strength therefore by heating the compact below melting point, strength can be achieved (increasing strength and hardness). This method of achieving strength in compact by heating is called as sintering process.
- Usually carried out at 70% to 90% of the metal's melting point (absolute scale)
- Transforms compacted mechanical bonds to much stronger metal bonds
- Generally agreed among researchers that the primary driving force for sintering is reduction of surface energy
- Part shrinkage occurs during sintering due to pore size reduction

Sintering

Sintering Sequence on a Microscopic Scale

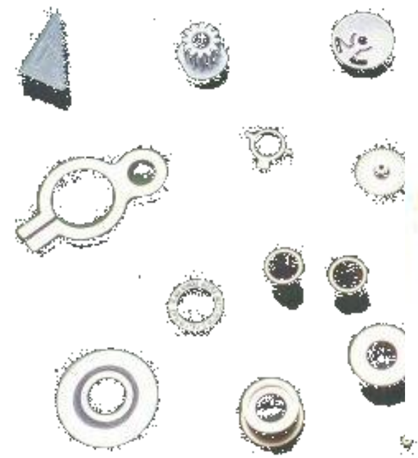
(1) Particle bonding is initiated at contact points; (2) contact points grow into "necks"; (3) pores between particles are reduced in size; (4) grain boundaries develop between particles in place of necked regions

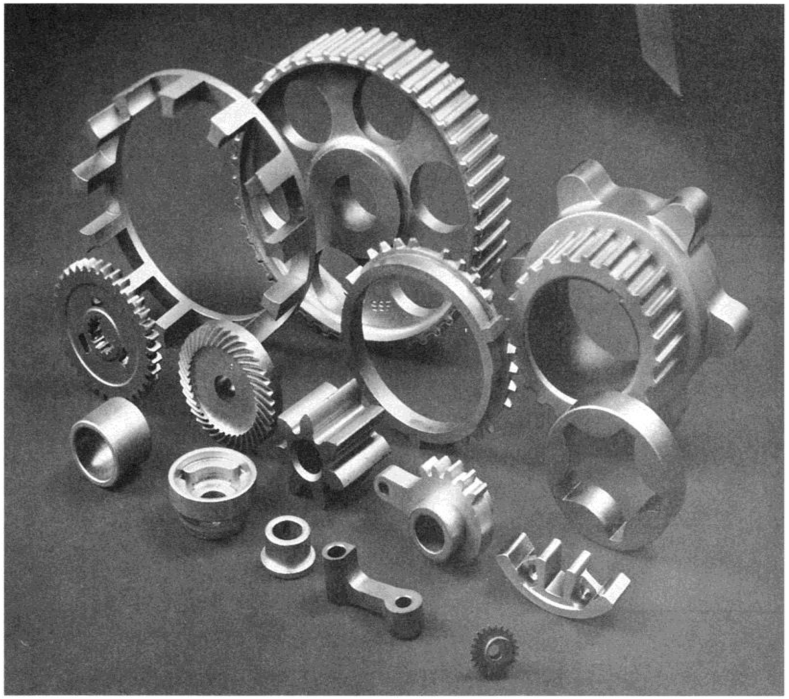


Sizing & Finishing or secondary operations

- Operations include repressing, grinding, plating can be done; They are used to ensure close dimensional tolerances, good surface finish, increase density, corrosion resistance etc.
- Secondary operations are performed on sintered part to increase density, improve accuracy, or accomplish additional shaping
  - Repressing - pressing in closed die to increase density and improve properties
  - Sizing - pressing to improve dimensional accuracy
  - Coining - pressing details into its surface
  - Machining - for geometric features that cannot be formed by pressing, such as threads and side holes
- However, to improve properties, finishing processes are needed:
  - Cold restriking, resintering, and heat treatment.
  - Impregnation of heated oil.
  - Infiltration with metal (e.g., Cu for ferrous parts).
  - Machining to tighter tolerance.

PM Products

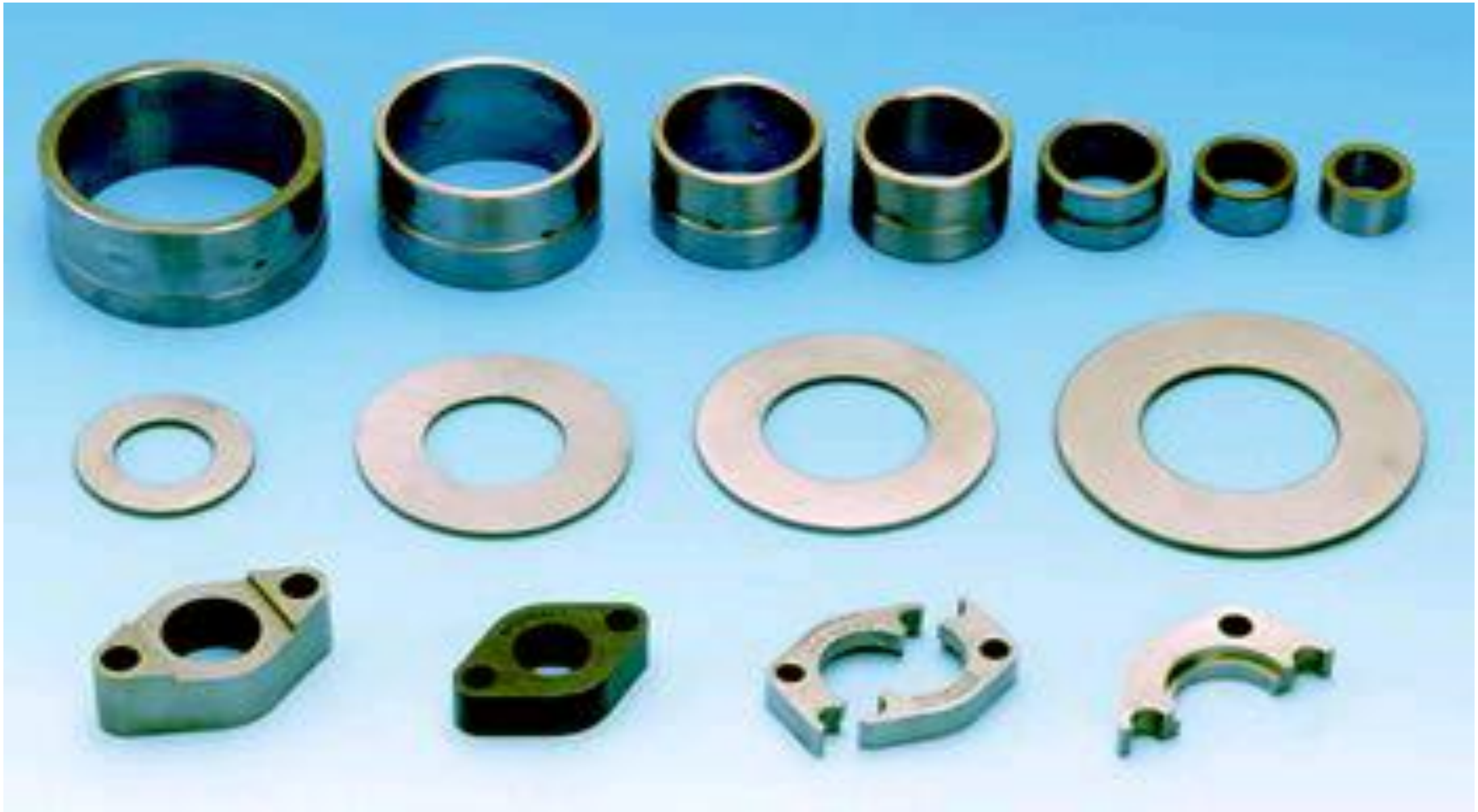




Motor Cycle Parts

Vehicles Engine Parts

Industrial Machines Parts



Industrial Machines Parts

For Electric Motors

Production of Metallic Powders

- In general, producers of metallic powders are not the same companies as those that make PM parts
- Any metal can be made into powder form
- Three principal methods by which metallic powders are commercially produced
  1. Atomization
  2. Chemical
  3. Electrolytic
- In addition, mechanical methods are occasionally used to reduce powder sizes

Production method of metal Powder

Atomization

This uses high pressure fluid jets to break up a molten metal stream into very fine droplets, which then solidify into fine particles

High quality powders of Al, brass, iron, stainless steel, tool steel, superalloys are produced commercially

Types: water atomization, gas atomization, soluble gas or vacuum atomization, centrifugal atomization, rotating disk atomization, ultrarapid solidification process, ultrasonic atomization

Mechanism of atomization:

In conventional (gas or water) atomization, a liquid metal is produced by pouring molten metal through a tundish with a nozzle at its base. The stream of liquid is then broken into droplets by the impingement of high pressure gas or water. This disintegration of liquid stream is shown in fig. This has five stages

i) Formation of wavy surface of the liquid due to small disturbances

ii) Wave fragmentation and ligament formation

iii) Disintegration of ligament into fine droplets

iv) Further breakdown of fragments into fine particles

v) Collision and coalescence of particles

- Atomization is a process where liquid metal is fragmented into small droplets that cool and solidify into fine particles by uses high pressure fluid jet.

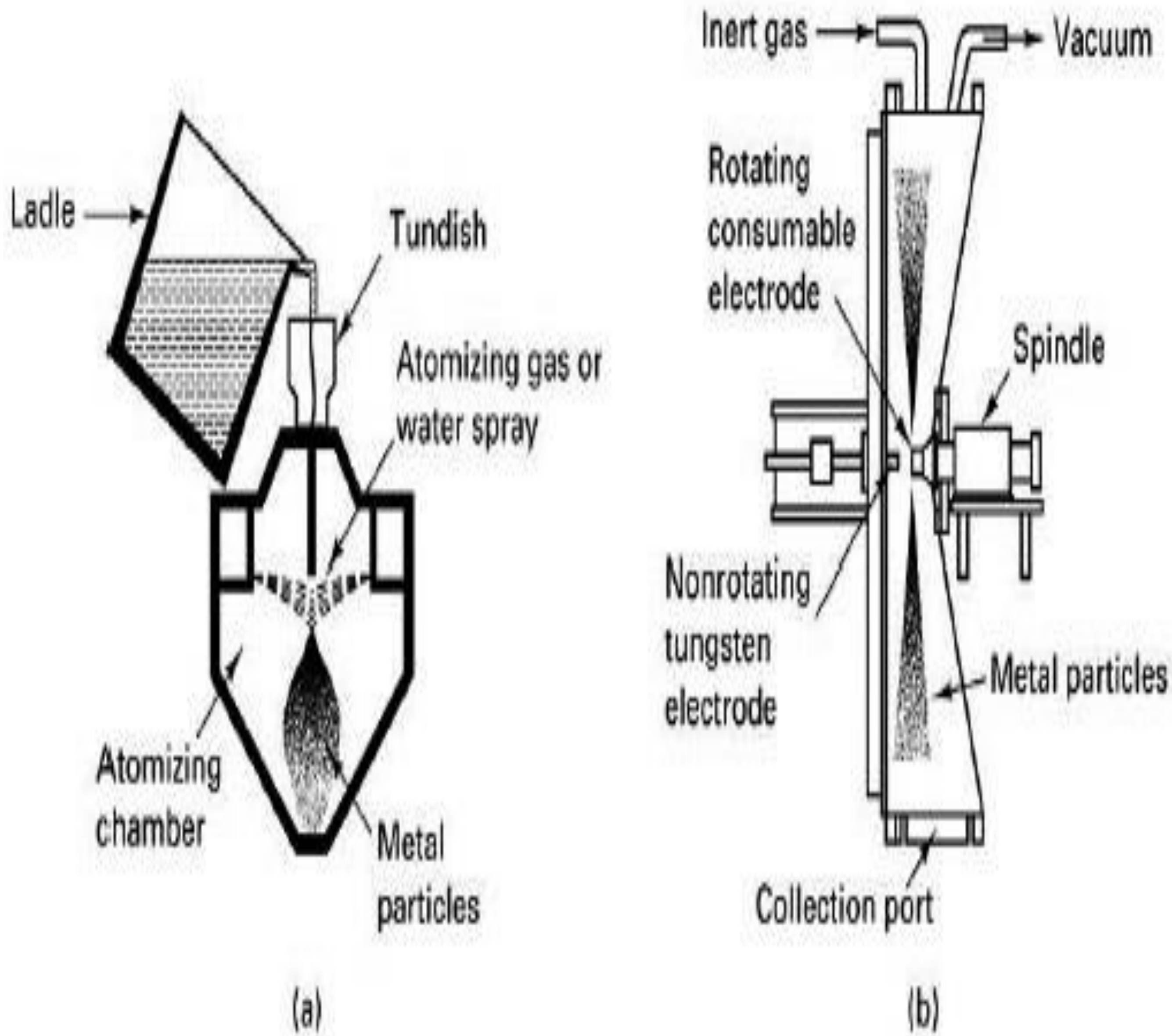
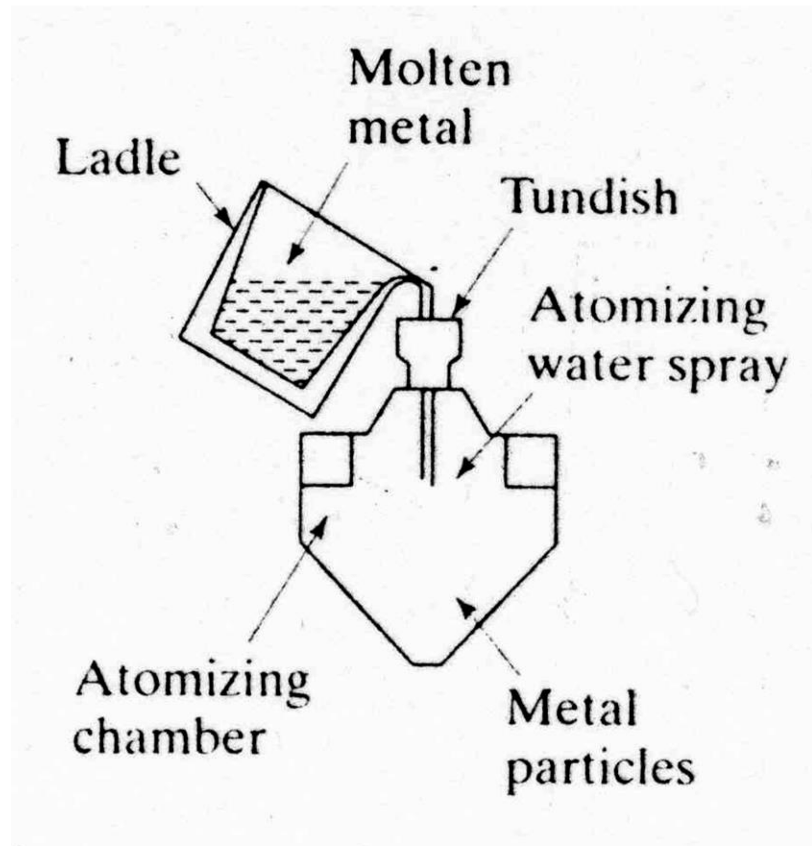


Figure Two methods for producing metal powders: (a) melt atomization and (b) atomization from a rotating consumable electrode.

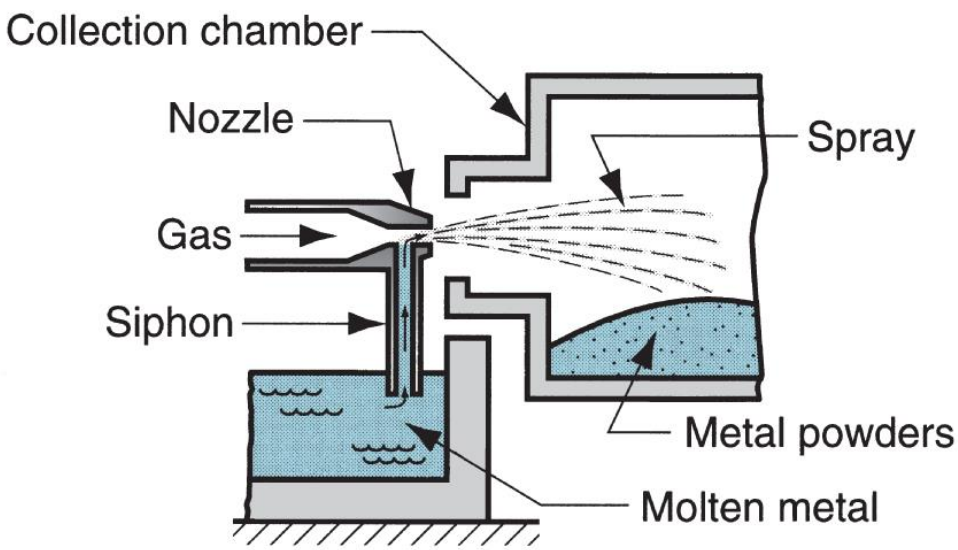
Atomization

- Produce a liquid-metal stream by injecting molten metal through a small orifice
- Stream is broken by jets of inert gas, air, or water
- The size of the particle formed depends on the temperature of the metal, metal flowrate through the orifice, nozzle size and jet characteristics

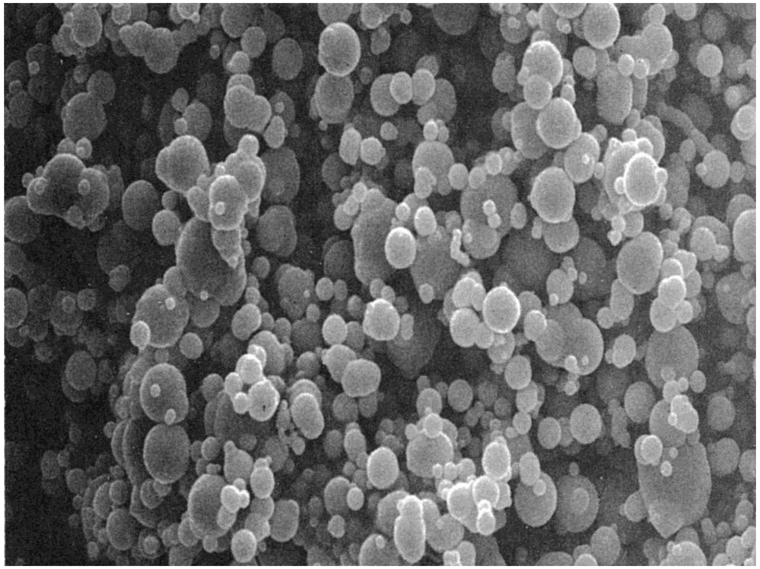


Gas Atomization Method

High velocity gas stream flows through expansion nozzle, siphoning molten metal and spraying it into container

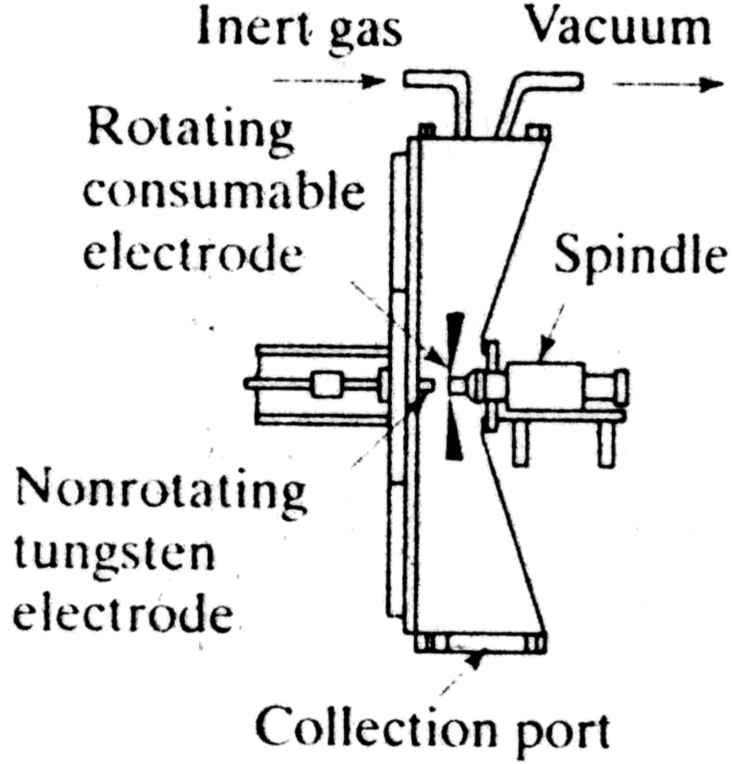


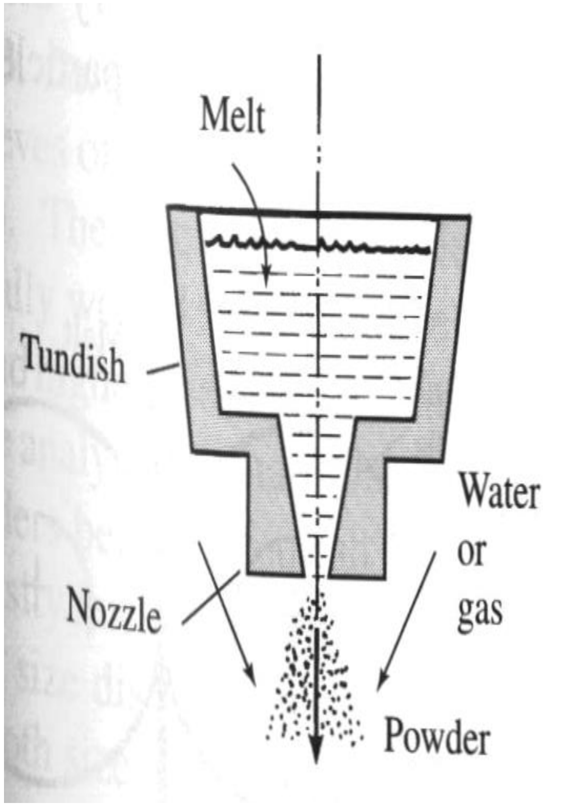
(a)

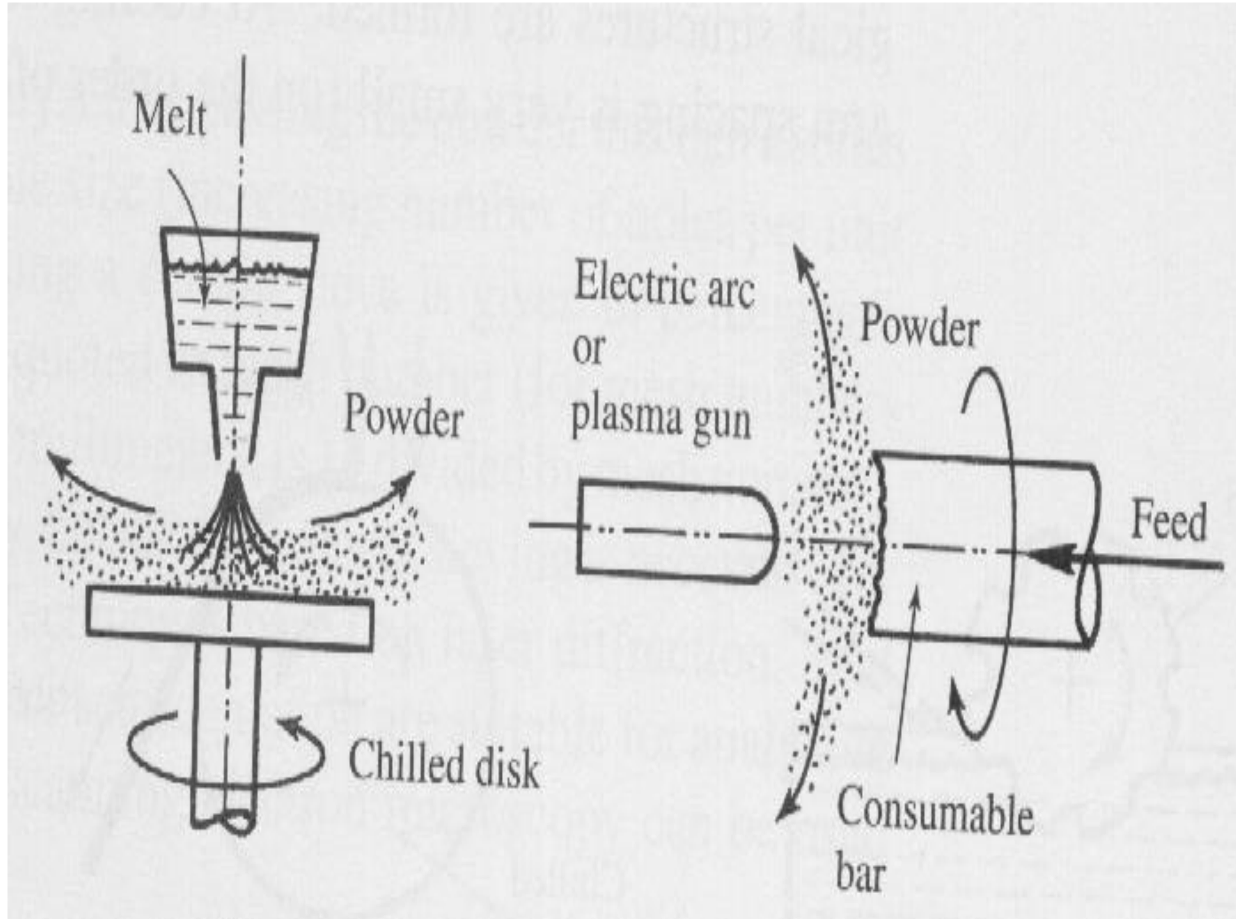


Electrode Centrifugation

A consumable electrode is rotated rapidly in a helium-filled chamber. The centrifugal force breaks up the molten tip of the electrode into metal particles.



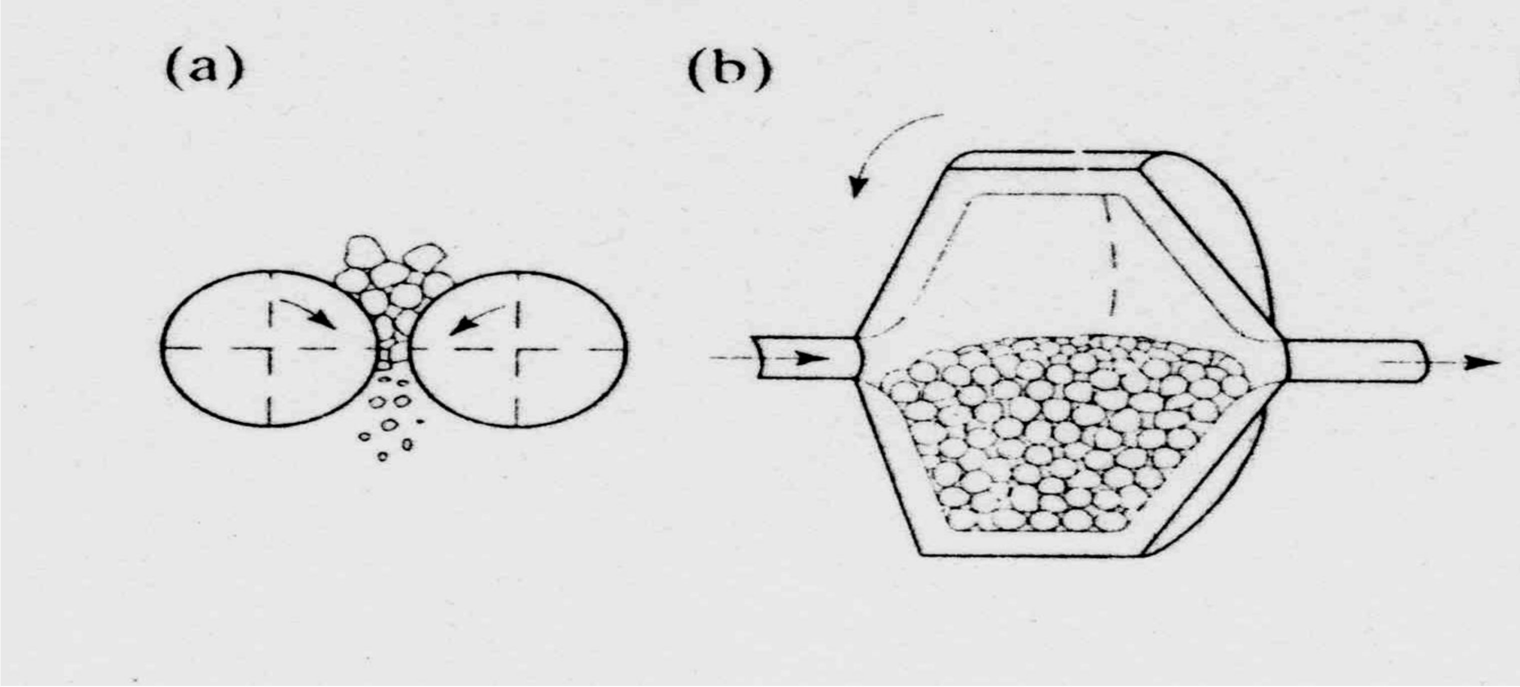




(a) (b) (c)

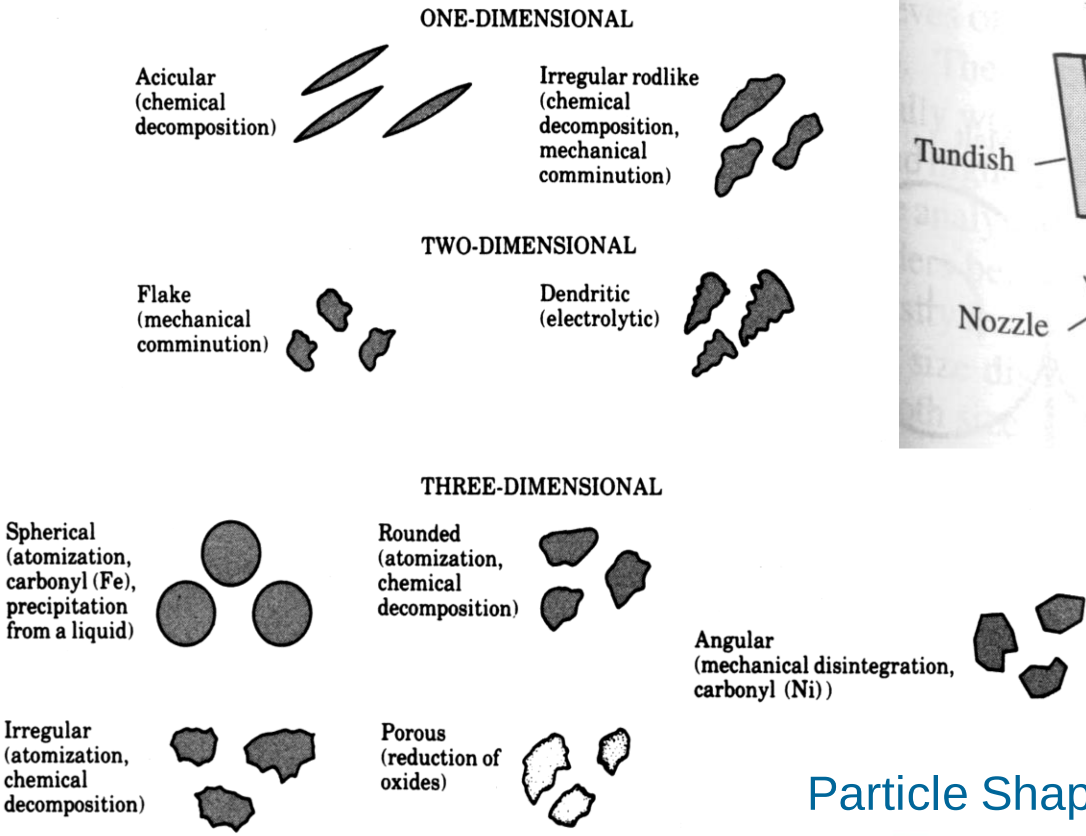
(a) Water or gas atomization; (b) Centrifugal atomization; (c) Rotating electrode

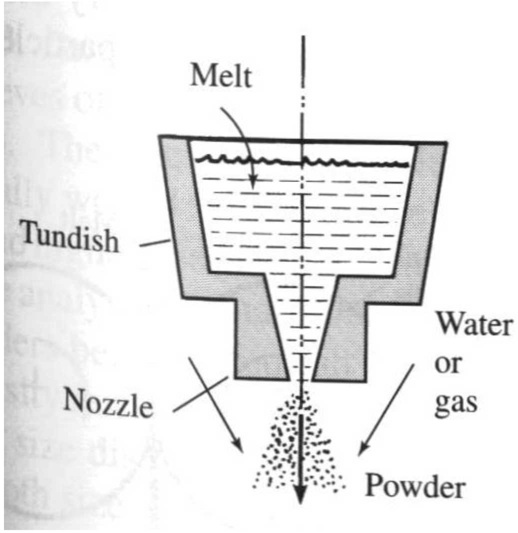
Powder Preparation



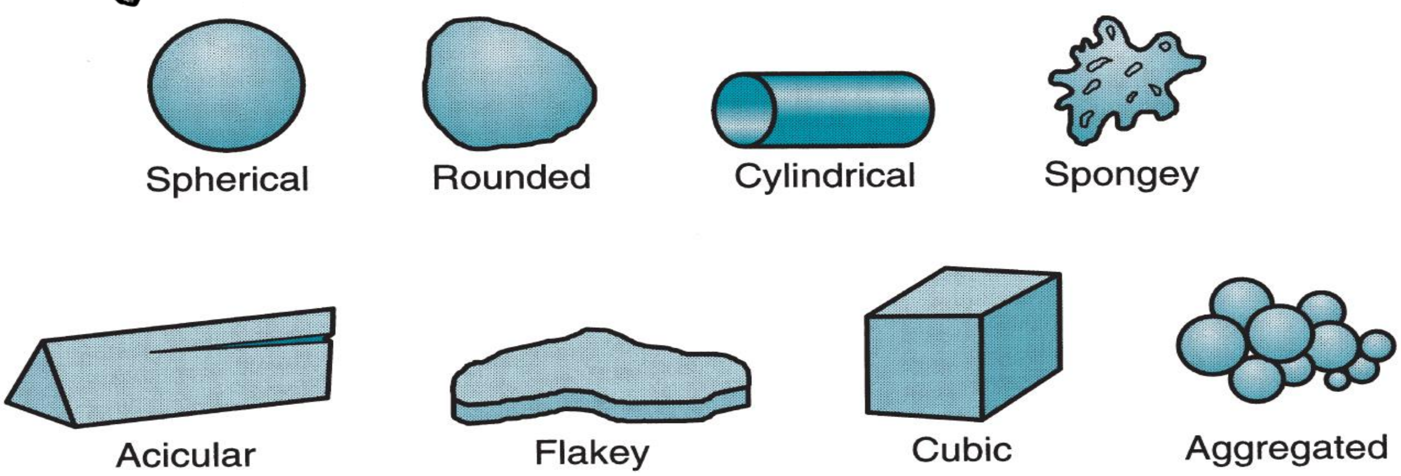
(a) Roll crusher, (b) Ball mill

Powder Production





Particle Shapes in PM



Impregnation and Infiltration

- Porosity is a unique and inherent characteristic of PM technology
- It can be exploited to create special products by filling the available pore space with oils, polymers, or metals
- Two categories:
  1. Impregnation
  2. Infiltration

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
- 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

- 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
- Heating the filler metal in contact with the sintered part so capillary action draws the filler into the pores
  - Resulting structure is nonporous, and the infiltrated part has a more uniform density, as well as improved toughness and strength

Advantages / Disadvantages P/M

- **Virtually unlimited choice of alloys, composites, and associated properties.**
  - **Refractory materials are popular by this process.**
- **Controlled porosity for self lubrication or filtration uses.**
- **Can be very economical at large run sizes (100,000 parts).**
- **Long term reliability through close control of dimensions and physical properties.**
- **Very good material utilization.**
- **Limited part size and complexity**
- **High cost of powder material.**
- **High cost of tooling.**
- **Less strong parts than wrought ones.**
- **Less well known process.**

P/M Applications

- Electrical Contact materials
- Heavy-duty Friction materials
- Self-Lubricating Porous bearings
- P/M filters
- Carbide, Alumina, Diamond cutting tools
- Structural parts
- P/M magnets
- Cermets
- and more, such as high tech applications

Materials and Products for PM

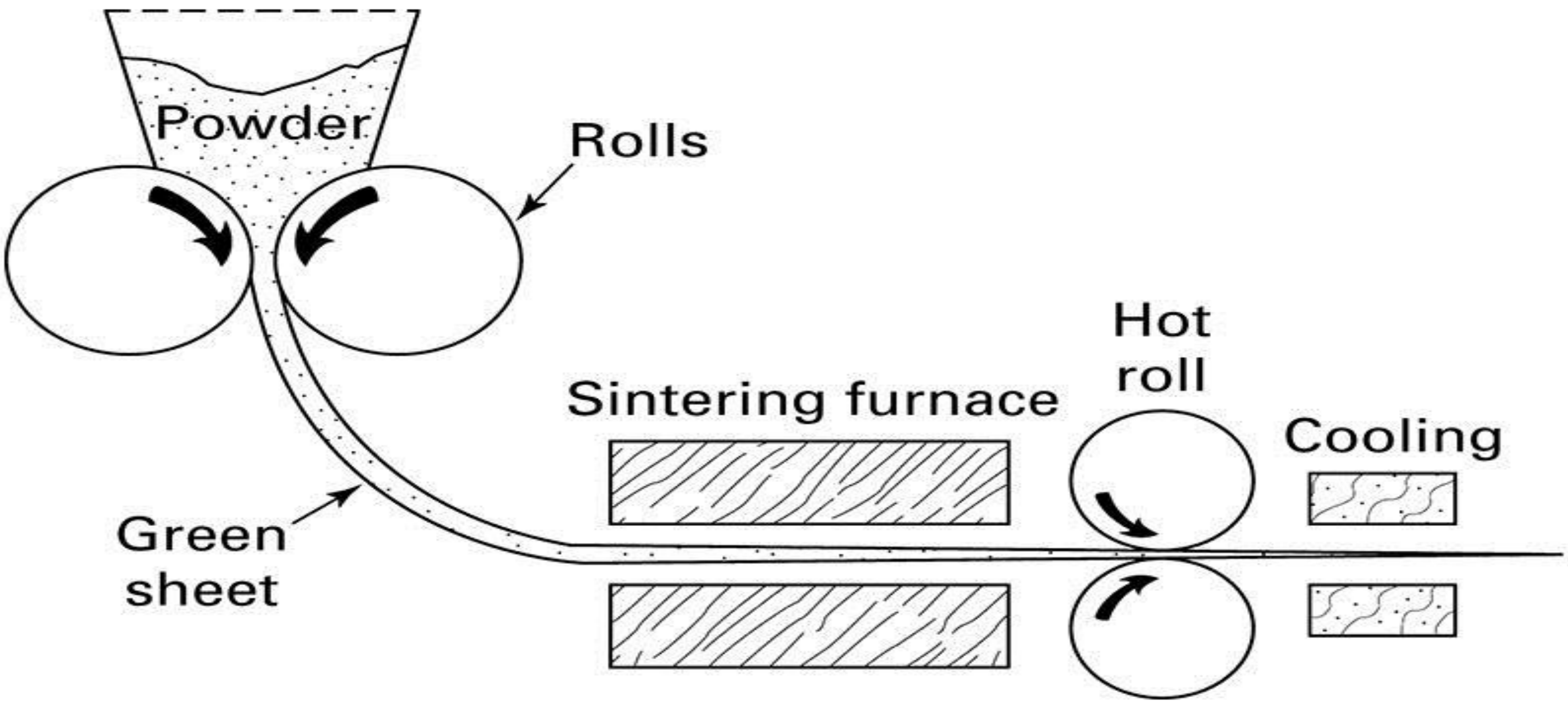
- Raw materials for PM are more expensive than for other metalworking because of the additional energy required to reduce the metal to powder form
- Accordingly, PM is competitive only in a certain range of applications
- What are the materials and products that seem most suited to powder metallurgy?

Q. What are the materials and products that seem most suited to powder metallurgy?

A pure metal in particulate form can be produced. Common elemental powders it can produce are Iron, Aluminum, Copper etc. Elemental powders can be mixed with other metal powders to produce alloys that are difficult to formulate by conventional methods Example: tool Steels. It can also produce metal alloy powder like stainless steel, superalloys, Ti alloy powders etc.

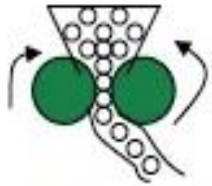
PM Products are Gears, bearings, sprockets, fasteners, electrical contacts, cutting tools, and various machinery parts etc. Advantage of PM: parts can be made to near net shape or net shape. When produced in large quantities, gears and bearings are ideal for PM because there is a need for porosity in the part to serve as a reservoir for lubricant

Powder Rolling



Powder rolling

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.

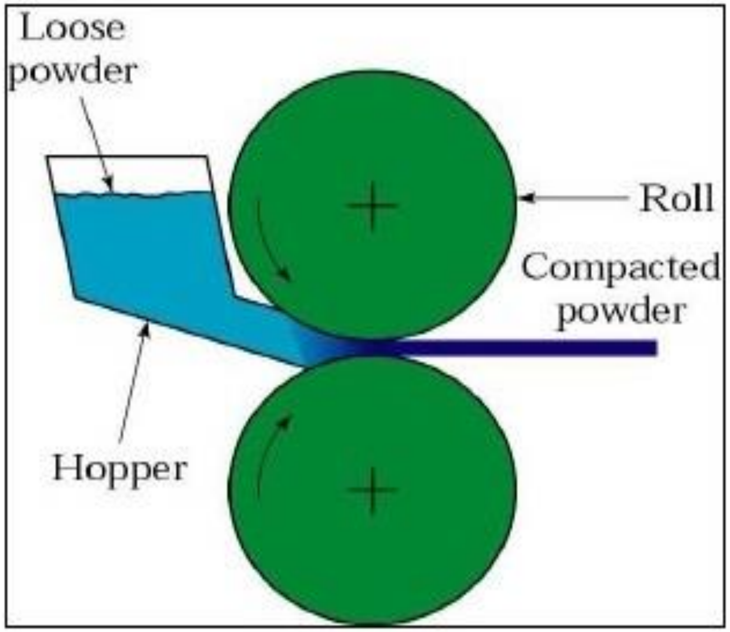


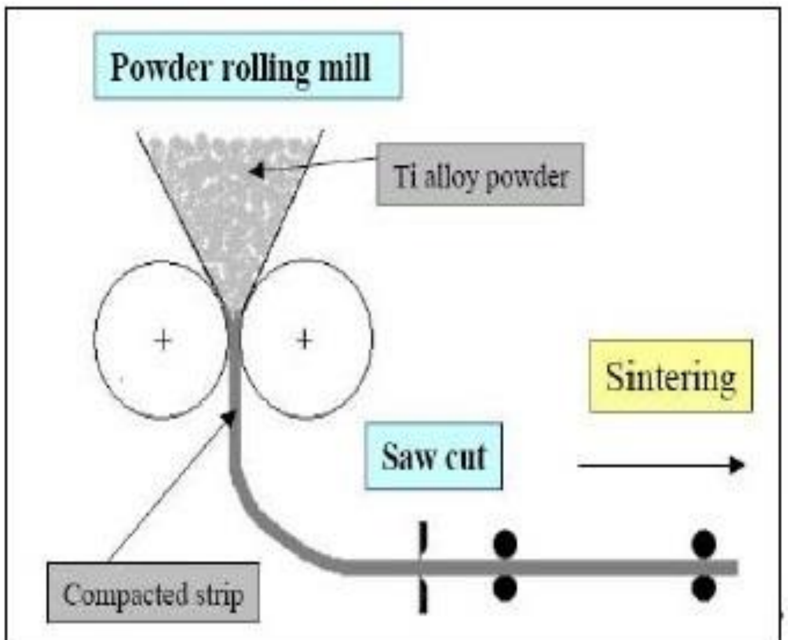
Steps: 1) preparation of green strip, 2) sintering, 3) densification of sintered strip, 4) final cold rolling and annealing

Parameters affecting powder rolling are roll gap, roll diameter, roll speed, powder characteristics; **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

In densification stage, either **repeated cold rolling followed by annealing** or **hot rolling of strip** can be followed

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.





12" wide Ti-6Al-4V strip

Figures from www.cems.uvm.edu/~ebuturla/, http://www.itponline.com/Presentations/ITA-2005.pdf

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