Powder Metallurgy

by
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Introduction

- *Powder metallurgy* = is the name given to the process by which fine powdered materials are blended, pressed into a desired shape (compacted), and then heated to bond surfaces (sintering).
- In a controlled atmosphere at a temperature below the melting point (usually 70-80% of the lowest melting point of the constituent metals).
- Typically used when large amounts of small, intricate parts with high precision are required
- Little material waste and unusual mixtures can be utilized
- Used for parts in the automotive industry, household appliances, and recreational equipment (to name a few)

Advantages

- High strength parts with low ductility metals and metals with very high melting temperatures.
- High tolerance parts possible with minimum processing.
- High alloy contents possible; often alloy content exceeds solubility limits of conventional wrought metallurgical processing.
- Ability to create complex shapes
- Low material waste
- Good microstructure control

Disadvantages

- Tooling costs may be high relative to conventional processing.
- Strength and stiffness may be inferior to wrought alloys of similar composition.
- Porosity and low ductility may impair durability.
- Fracture Toughness may be low.

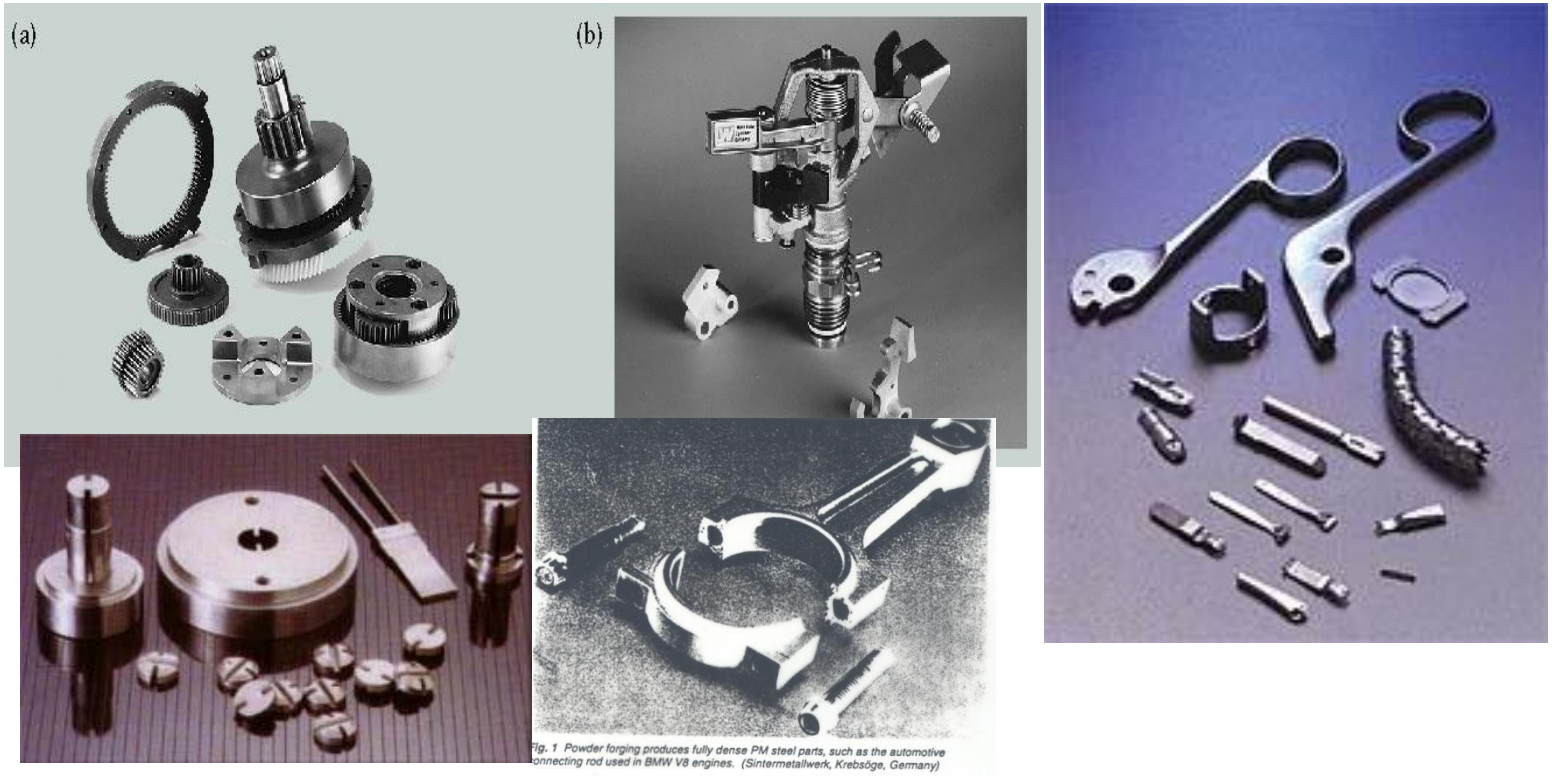
Typical Applications for Metal Powders

TABLE 11.1

Application	Metals	Uses
Abrasives	Fe, Sn, Zn	Cleaning, abrasive wheels
Aerospace	Al, Be, Nb	Jet engines, heat shields
Automotive	Cu, Fe, W	Valve inserts, bushings, gears
Electrical/electronic	Ag, Au, Mo	Contacts, diode heat sinks
Heat treating	Mo, Pt, W	Furnace elements, thermocouples
Joining	Cu, Fe, Sn	Solders, electrodes
Lubrication	Cu, Fe, Zn	Greases, abradable seals
Magnetic	Co, Fe, Ni	Relays, magnets
Manufacturing	Cu, Mn, W	Dies, tools, bearings
Medical/dental	Ag, Au, W	Implants, amalgams
Metallurgical	Al, Ce, Si	Metal recovery, alloying
Nuclear	Be, Ni, W	Shielding, filters, reflectors
Office equipment	Al, Fe, Ti	Electrostatic copiers, cams

Source: R. M. German.

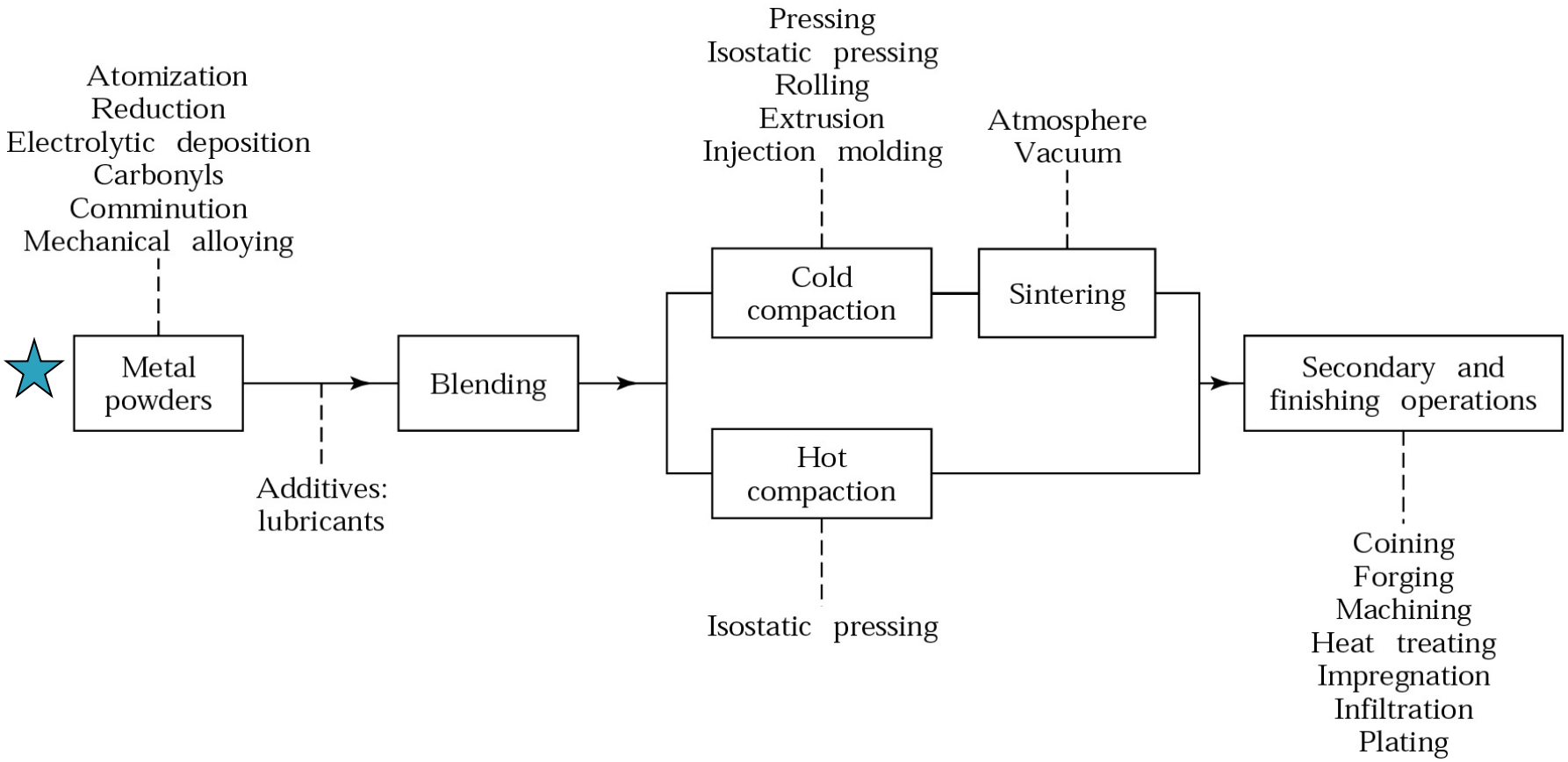
Powder Metallurgy



a. Examples of typical parts made by powder-metallurgy processes; gears, cams, bushings, cutting tools, porous, tiny balls, etc.

b. Upper trip lever for a commercial irrigation sprinkler, made by P/M. this part is made of unleaded brass alloy; it replaces a die-cast part, with a 60% savings.

Powder Metallurgy Process



Method of Powder Production

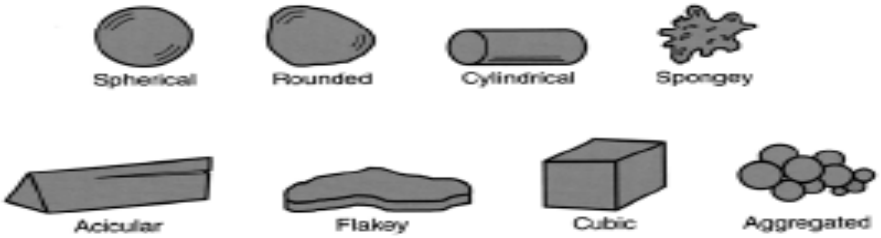
- Properties of powder metallurgy products are highly dependent on the characteristics of starting powders

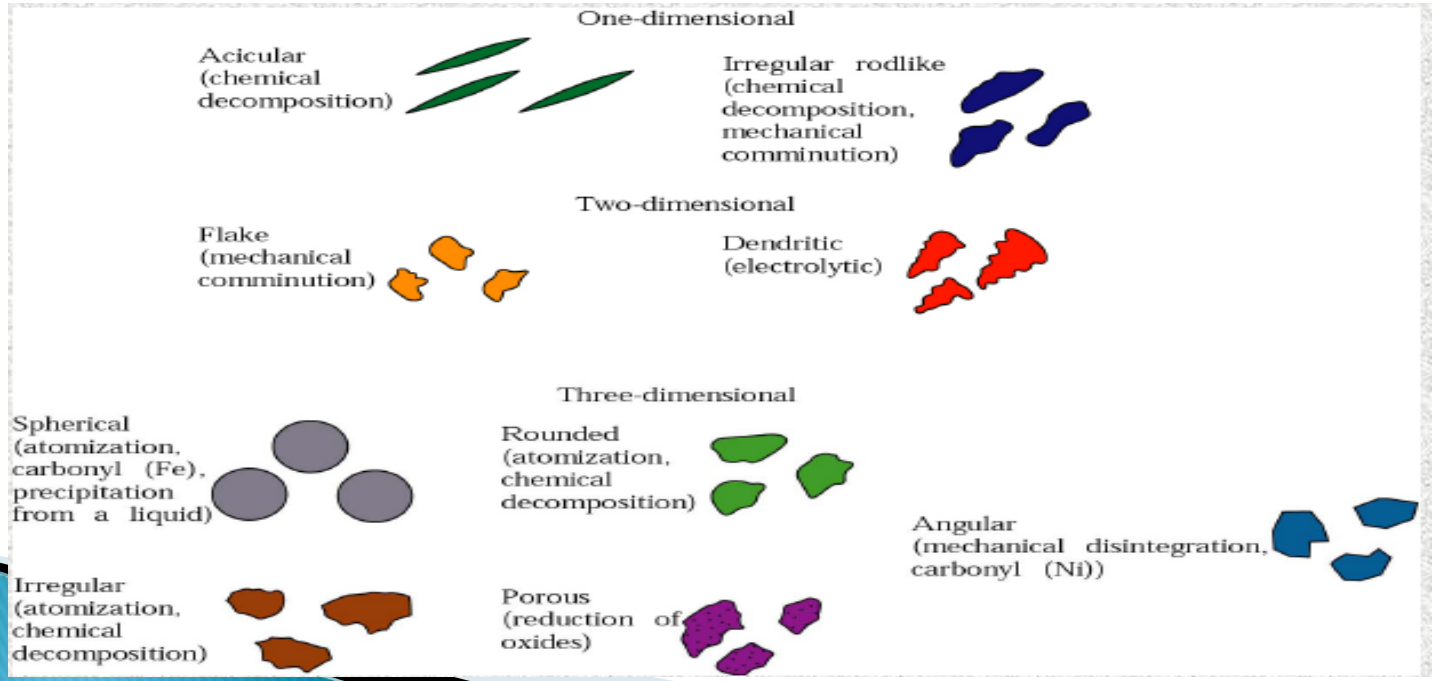
- Some important properties and characteristics
  - Chemistry and purity (analysis using XRF)
  - Particle size (analysis using screening)
  - Size distribution (analysis using screening)
  - Particle shape (analysis using microscopic analysis)
  - Surface texture (analysis using microscopic analysis)

- Useful in producing prealloyed powders
  - Each powder particle can have the desired alloy composition

Method of Powder Production

- Particel sizes range : 0,1 µm – 1000 µm



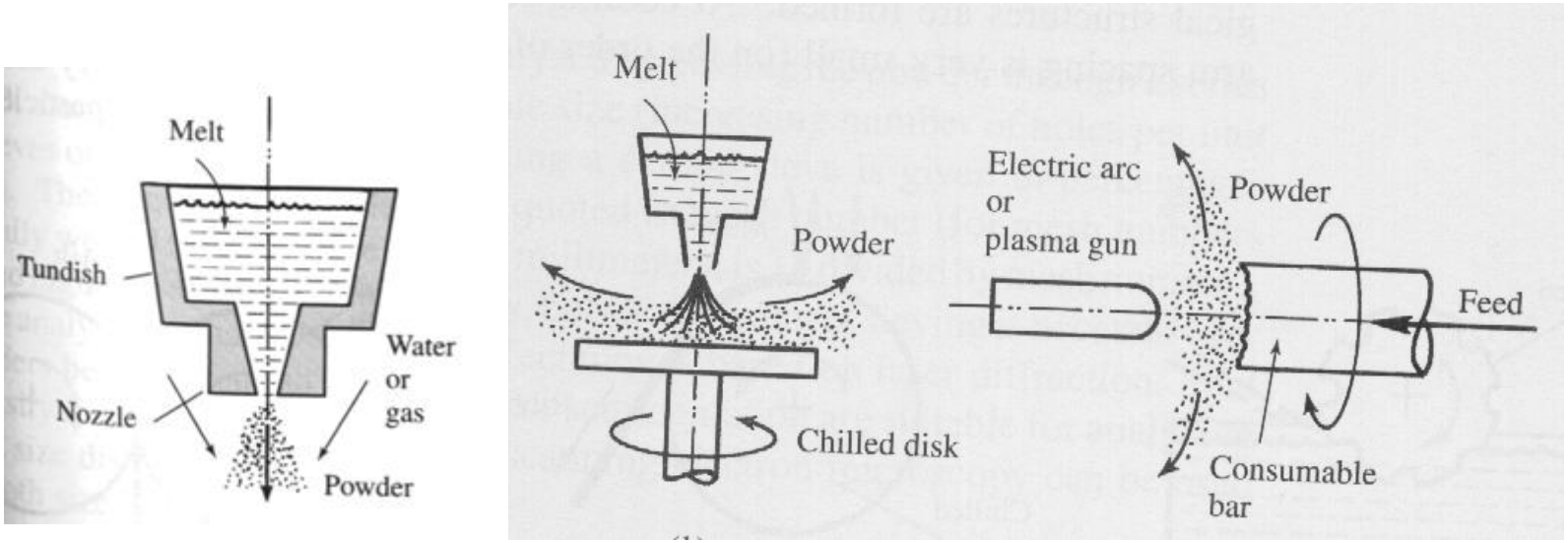


Method of Powder Production

- Atomization
  - Produces a liquid-metal stream by injecting molten metal through small orifice. The stream is broken up by jets of inert gas, air, or water.
  - The size of the particles formed depends on the temperature of the metal, rate of flow, nozzle size, and jet characteristic.

Method of Powder Production

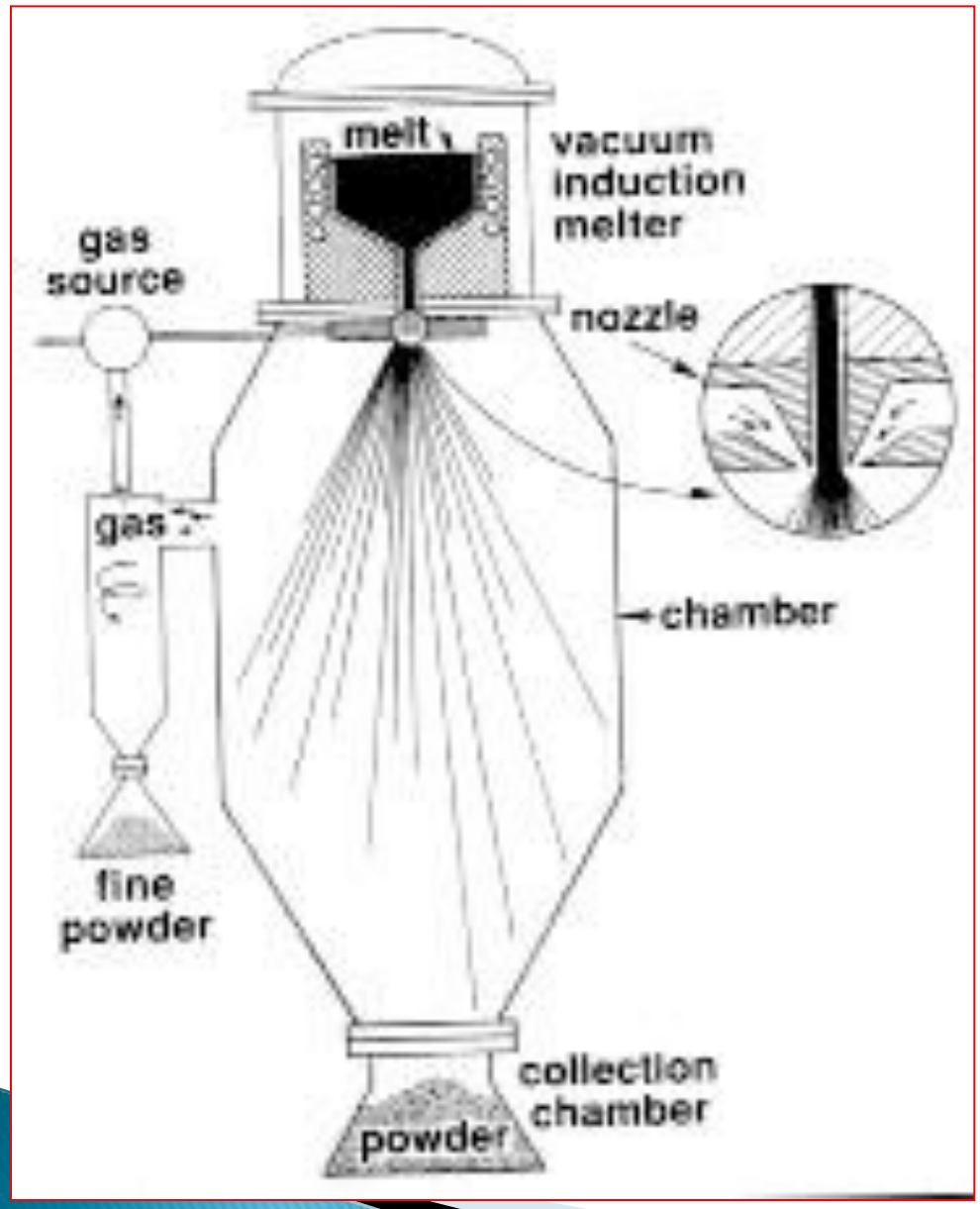
- Atomization



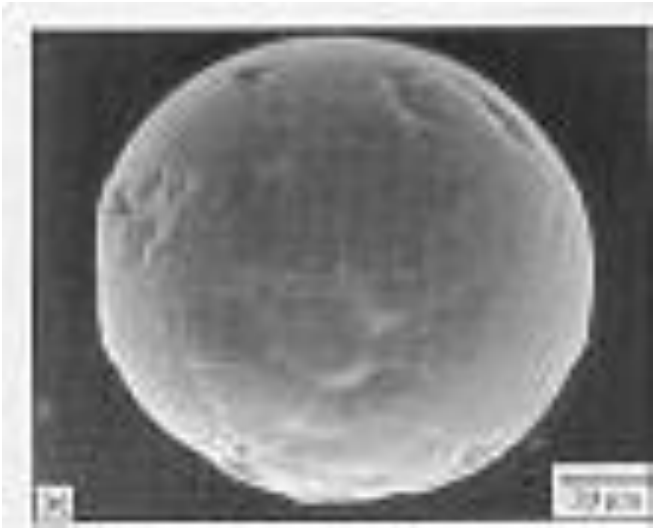
(a) (b) (c)

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

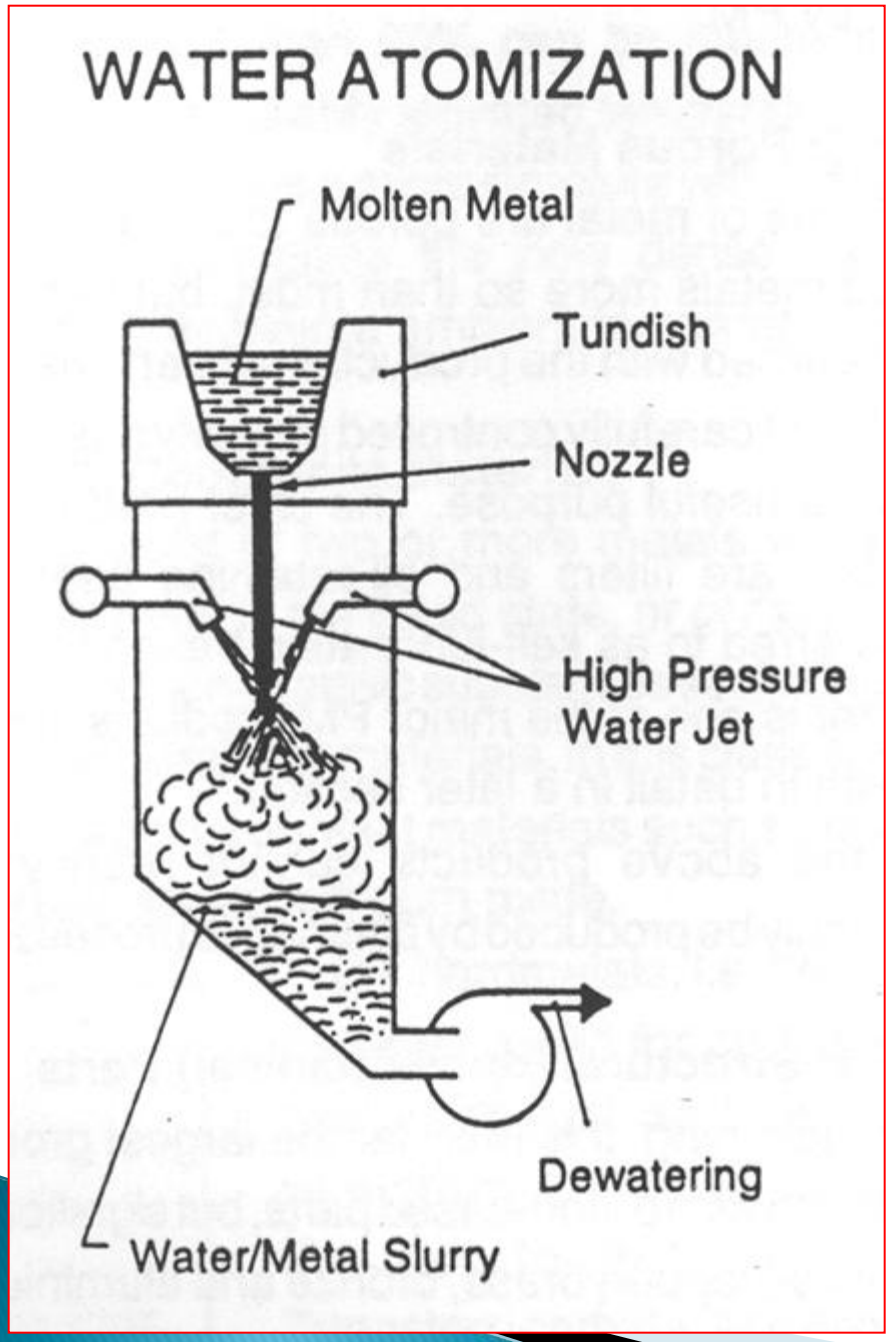
GAS ATOMIZATION

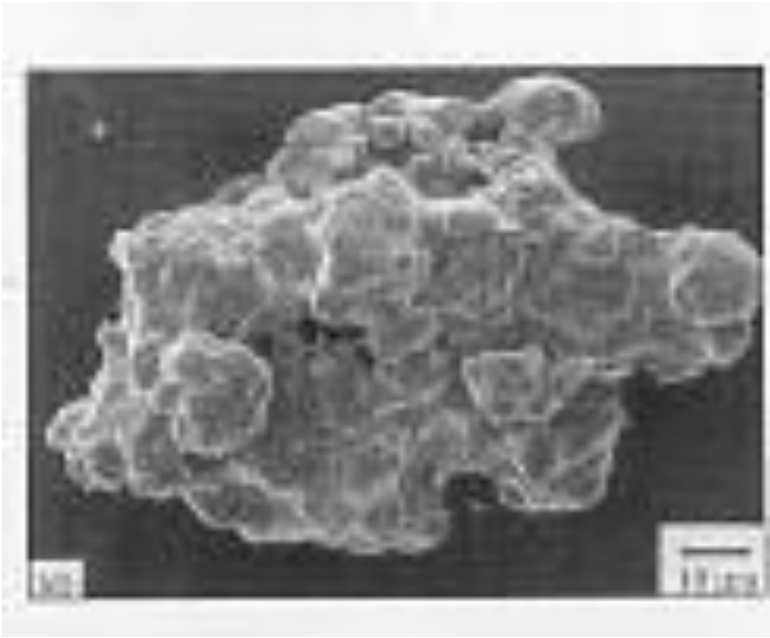


Method of Powder Production



Method of Powder Production





Method of Powder Production

- Reduction
  - Uses gases (hydrogen and CO) to remove oxygen from metal oxides.
  - The powders produced by this method are spongy and porous, and have uniformly size spherical or angular shape.

Method of Powder Production

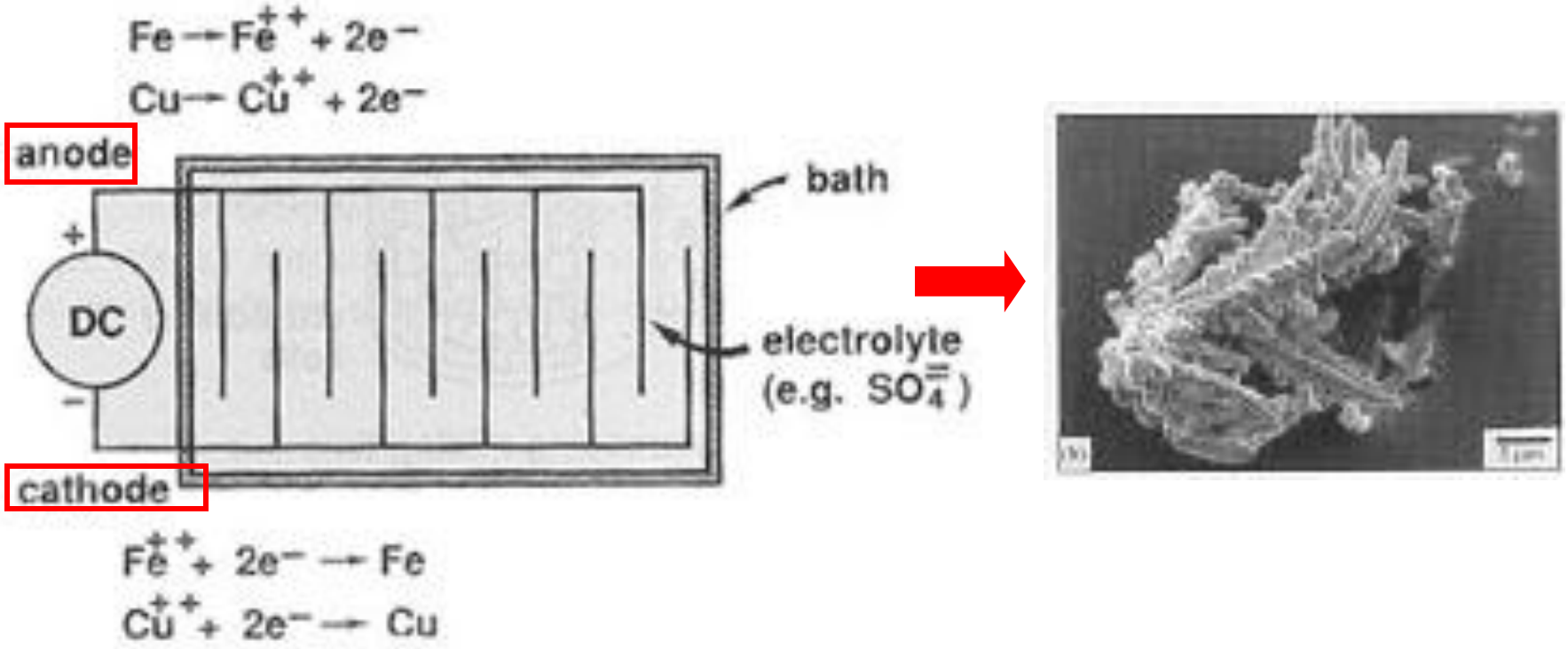
- Electrolytic deposition
  - Utilizes aqueous solutions or fused salts.
  - By choosing suitable conditions, such as electrolyte composition and concentration, temperature, and current density, many metals can be deposited in a spongy or powdery state.
  - Further processing–washing, drying, reducing, annealing, and crushing–is often required, ultimately yielding high-purity and high-density powders.

Method of Powder Production

- Electrolytic deposition
  - Copper is the primary metal produced by electrolysis but iron, chromium, and magnesium powders are also produced this way.
  - Due to its associated high energy costs, electrolysis is generally limited to high-value powders such as high-conductivity copper powders

Method of Powder Production

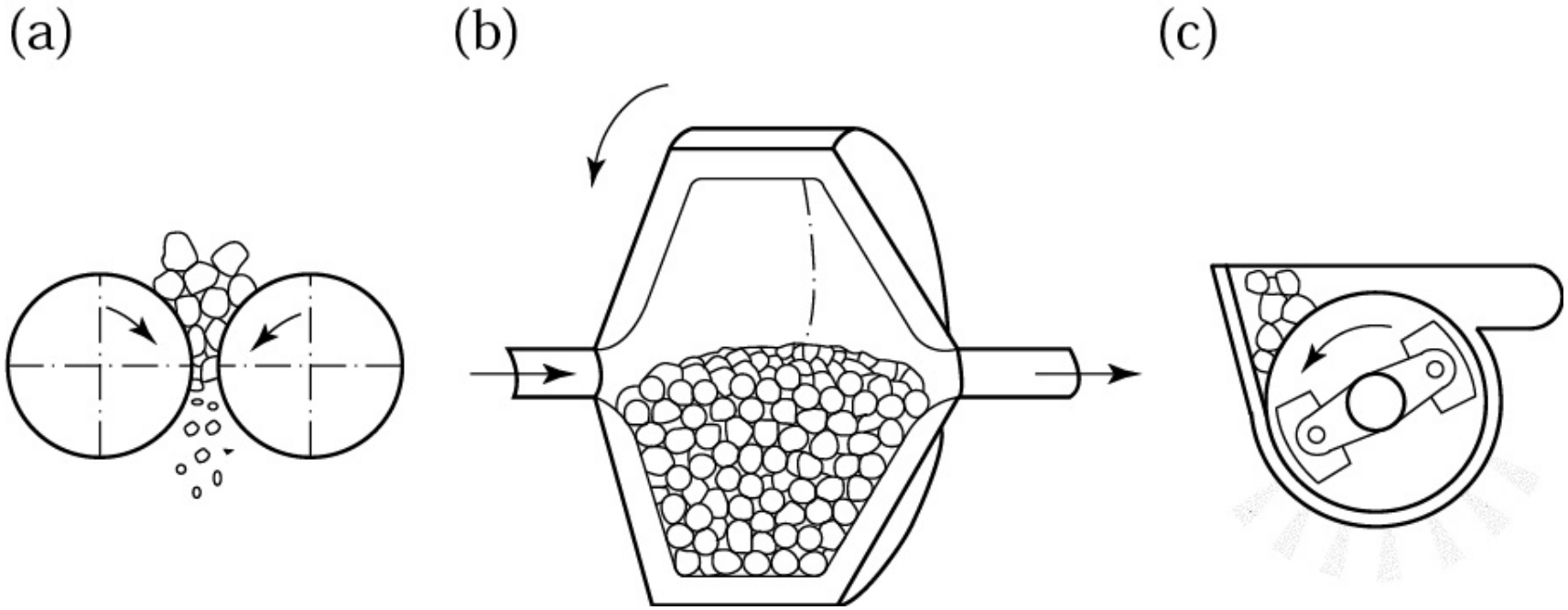
- Electrolytic deposition



Method of Powder Production

- Carbonyls
  - Are formed by letting iron or nickel react with CO. The reaction products are then decomposed to iron and nickel.
- Comminution
  - Mechanical comminution involves crushing, milling in a ball mill.
- Mechanical alloying
  - Powders of two or more pure metals are mixed in a ball mill. This process forms alloy powders

Mechanical Comminution/pulverization

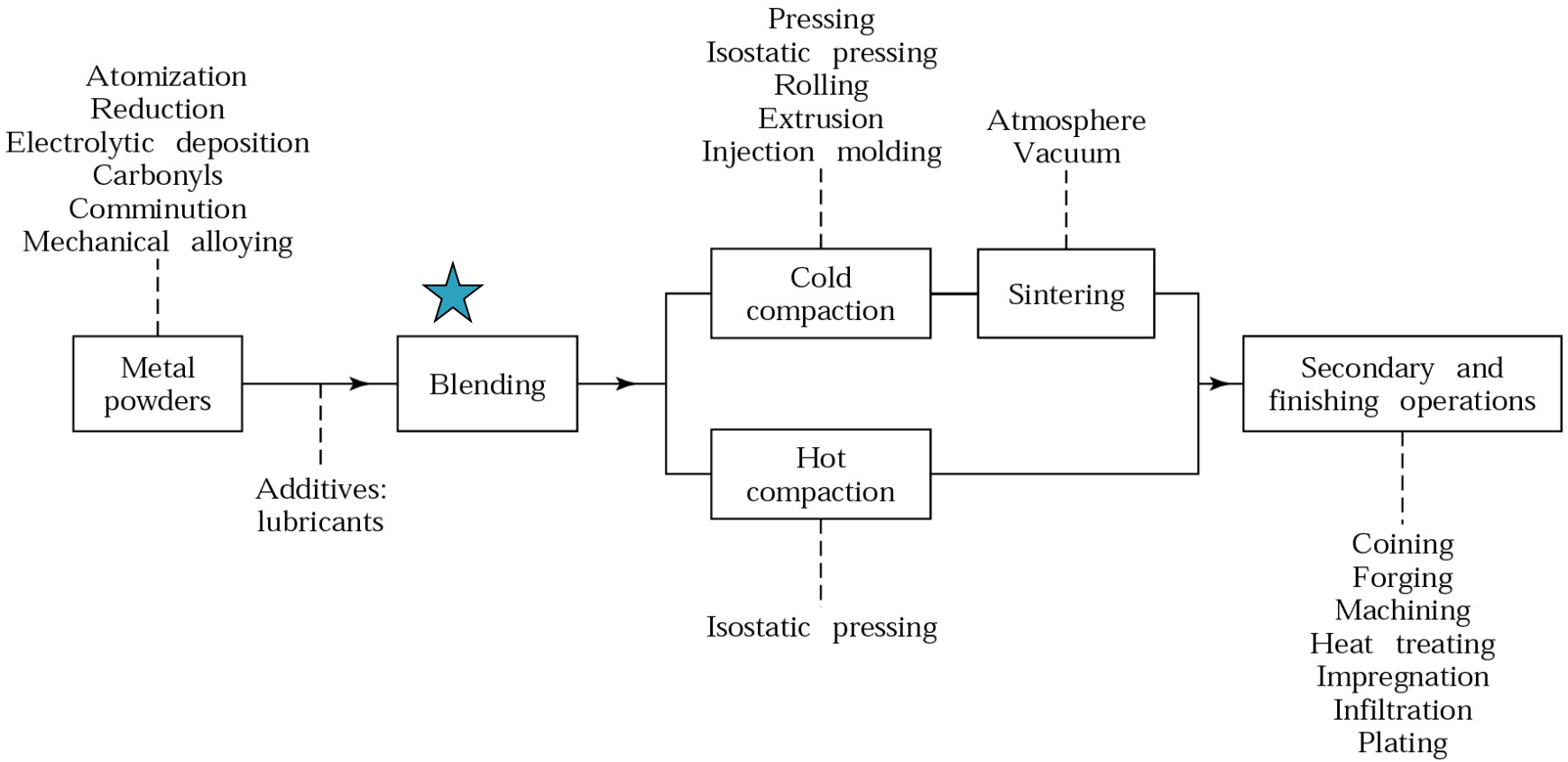


(a) roll crushing, (b) ball mill, and (c) hammer milling.

Additional Methods of Powder Manufacture

- Methods
  - Pulverization or grinding
  - Thermal decomposition of particulate hydrides
  - Precipitation from solution
  - Condensation of metal vapors
  - Nanopowders
  - Microencapsulated powders
- Almost any metal or alloy can be converted into powder

Powder Metallurgy Process



References

- M. P. Groover, “Fundamentals of Modern Manufacturing 2/e”, 2002 John Wiley & Sons, Inc.
- Kalpakjian & Schmid, “Manufacturing Processes for Engineering Materials, 1997, Addison Wesley