Powder Metallurgy (PM)

Definition

Powder Metallurgy is a metal processing technology in which parts are produced from metallic powders.

What are powders and their characteristics ?

Powders are finely divided solid whose maximum dimension is less than 1 mm. Their characteristics are as follows:

- Relatively high surface area to volume ratio
- Powders can exhibit behaviour intermediate to a solid and liquid
- Powders can flow under gravity to fill die cavities.
- Powders are compressible. Compression of metal powders is irreversible process.

Why Powder Metallurgy ?

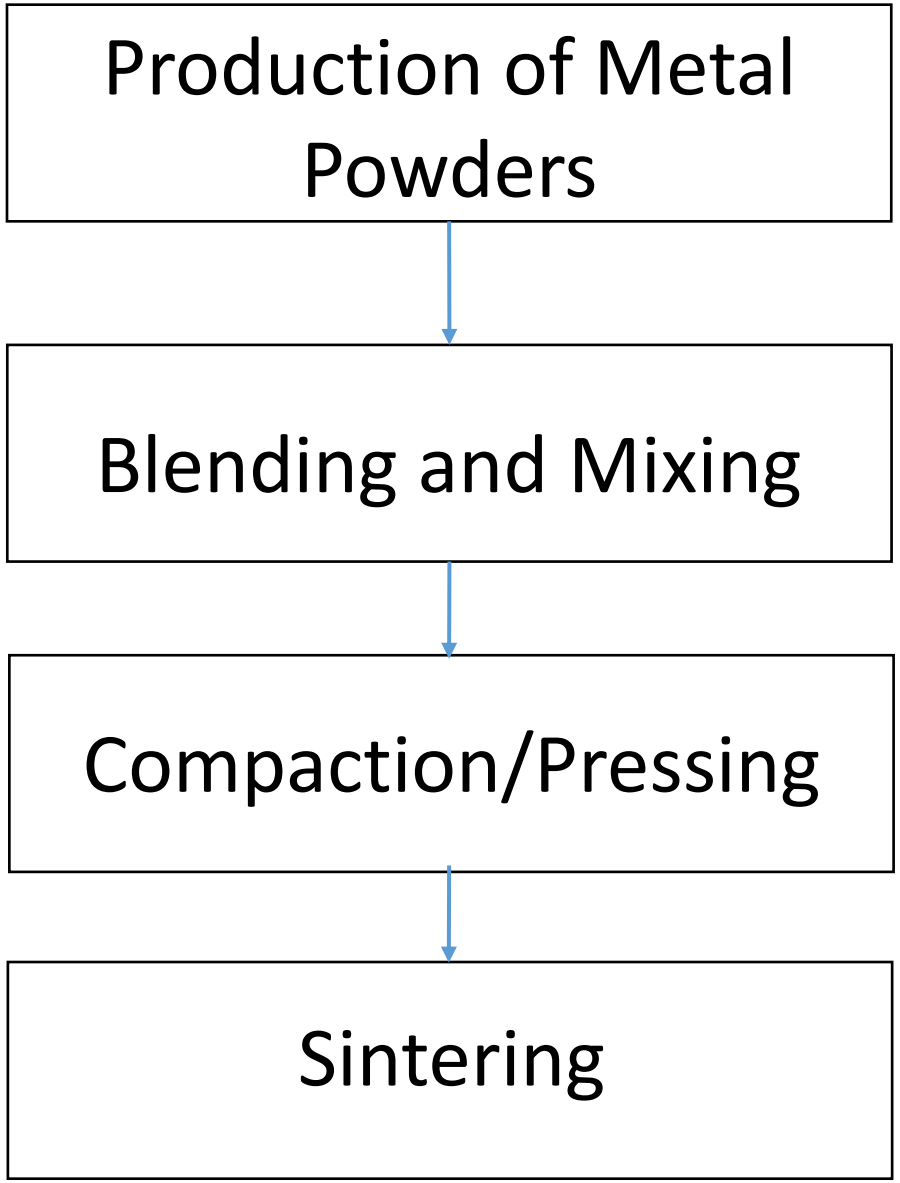
- For those metals whose melting point is too high (W, Mo)
- For those metals which react on melting
- It is used for metals that are too hard to machine
- To produce parts having certain level of porosity (E.g. Self Lubricating Bearings/ Oil-impregnated Bearings)
- It is helpful in producing very large quantities of the product

Powder Metallurgy-Competitive Edge

- Availability of wide variety of metal powders - Tailoring the raw materials to suit variety of applications. (E.g. , lead-copper for bearing surface)

- It is mostly a Net Shape process. The shape of the product can be imparted without any subsequent machining/finishing/coating. The product formed is ready to use.

Sequence of operations in powder metallurgy



Parameters of Metal Powders

- Powder size, distribution of powder size and shape of the metal powders of the metal powder affect the properties of the compacted product (density, porosity and compressibility).

- Powder/Particle size is measured through *screening*
  - *Passing the metal powders through a set of sieves of various mess sizes*
  - *Higher mesh count implies smaller or finer powders*

- Larger (coarser) particle size implies higher porosity.

Parameters of Metal Powders

- Distribution of Particle Size - Particle sizes are varying for a powder. 10% of particles may have certain size, 20% may be of different size, and so on. The size comprising 50% of the powder is known as the mode size of the powder.

- Shape of the particles are important. They are characterised by the aspect ratio. It is the ratio of maximum to minimum dimension of a particle. E.g., *The spherical particle will have aspect ratio unity.*

Production of Metal Powders

The size of the particles, their shape and size distribution, depend largely on the powder production processes. Broadly, there are three methods to obtain metal powders:

- Atomisation- Conversion of molten metal into a spray of droplets that solidify into powders.

- Chemical Reduction- Metallic compounds are reduced to elemental metal powders.

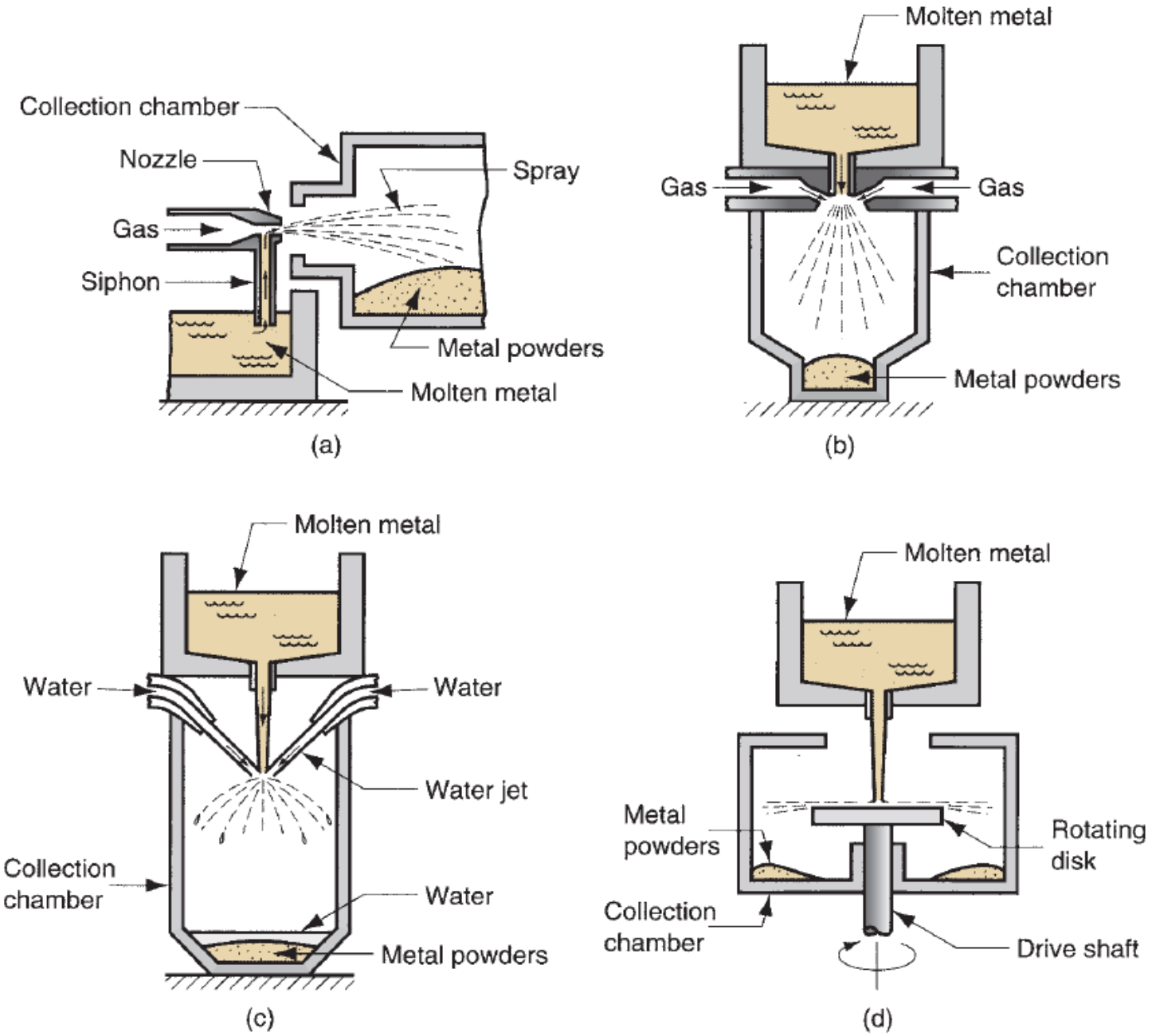
- Electrolysis- An electrolytic cell is set up which the source of the desired metal is anode. The anode is slowly dissolved under an applied voltage, transported through the electrolyte, and deposited on the cathode. The deposit is washed and dried to yield powders.

Atomisation

This method involves the conversion of molten metal into a spray of droplets that solidify into powders. There are multiple ways of creating molten metal spray :

- Gas Atomisation
- Water Atomisation
- Centrifugal Atomisation

Atomisation



a) and b) gas atomisation methods; c) water atomisation and d) centrifugal atomisation by rotating disc method.

*Figure 1- Atomisation Methods (refer to the textbook)

Atomisation

- **Gas Atomisation-** A high velocity gas stream is utilized to atomize the liquid metal. In Figure 1(a), gas flows through an expansion nozzle, siphoning the molten metal from below and spraying it into an container. The droplets solidify into powder from. In Figure 1(b), molten metal flows by gravity through a nozzle and is immediately atomized by air jets. The metal powders produced herein tend to be spherical.

- **Water Atomisation**-This type of atomisation is suited for metals that melt below 1600^0C. Cooling is more rapid and the particle shape is irregular. Also, formation of oxide layer on particle surface is possible. Therefore, recently, synthetic oil is used in place of water.

(*In both processes, particle size is inversely related to the velocity of the fluid stream*)

- **Centrifugal Atomisation**-Liquid metal stream pours on a rotating disc that sprays metal in all directions.

Blending and Mixing

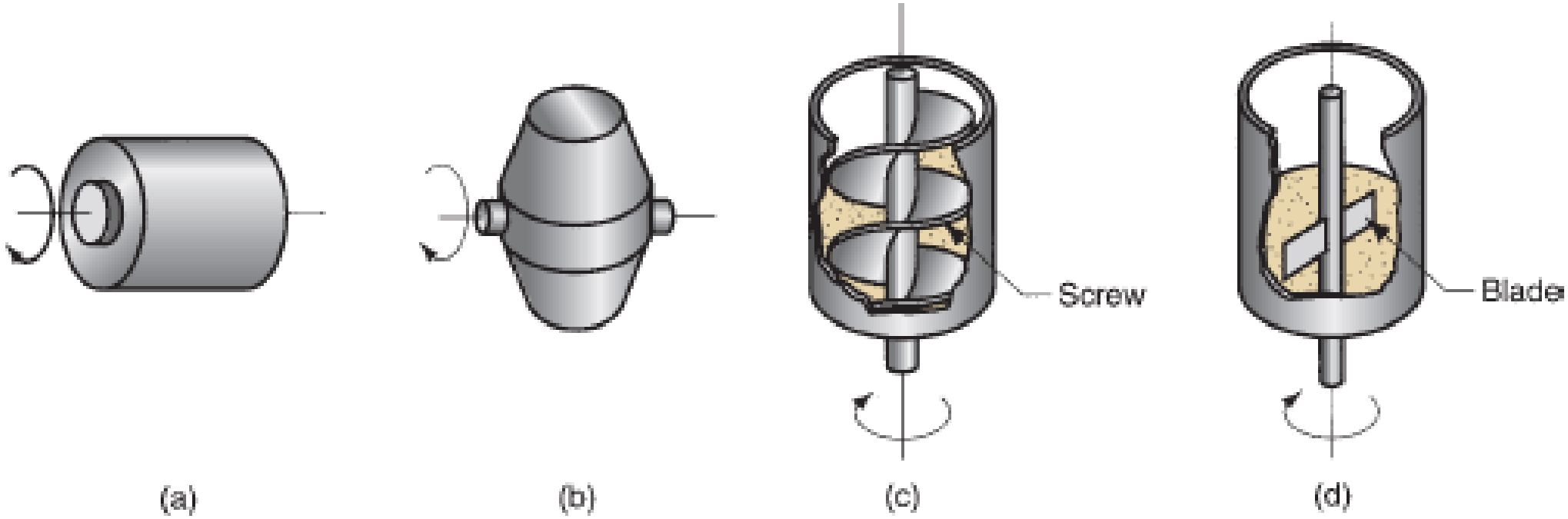
- Blending refers to when powders of the same chemical composition but different particle sizes blended to reduce porosity.

- Mixing refers to powders of different chemistries being combined.

- An advantage of PM is the opportunity to mix various metals into alloys that would be difficult to produce otherwise.

- Additives which include (1) lubricants, to reduce inter-particle friction and friction with die wall, (2) binders, required to achieve adequate strength in the pressed part; and (3) deflocculants, which inhibit agglomeration of powders

Blending and Mixing – Blending and Mixing Devices

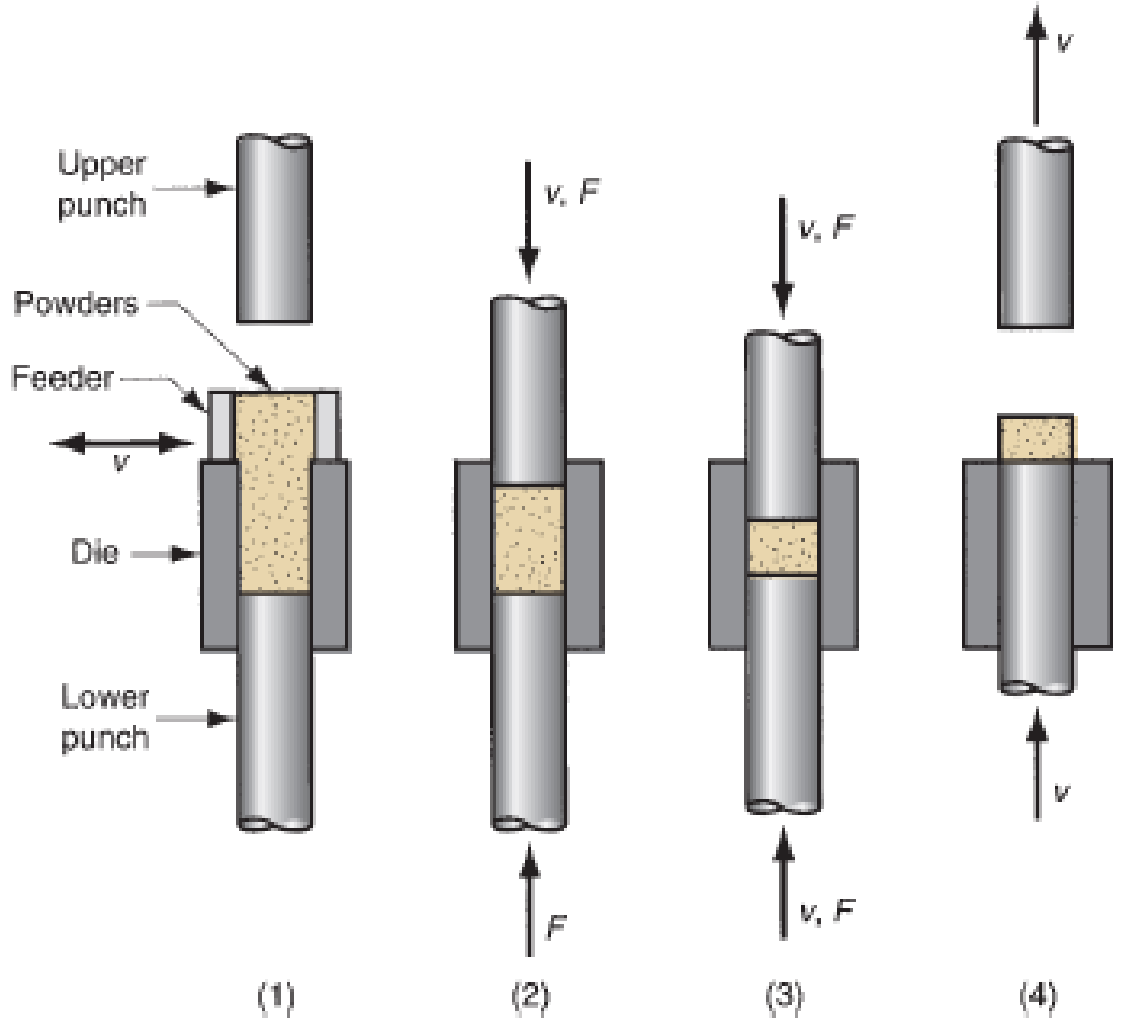


Blending and mixing are accomplished by mechanical means. (a) rotation in a drum; (b) rotation in a double cone container, (c) rotation in a screw mixer and (d) blade mixer

Compaction

- High pressure is applied to the powders to form them into the required shape

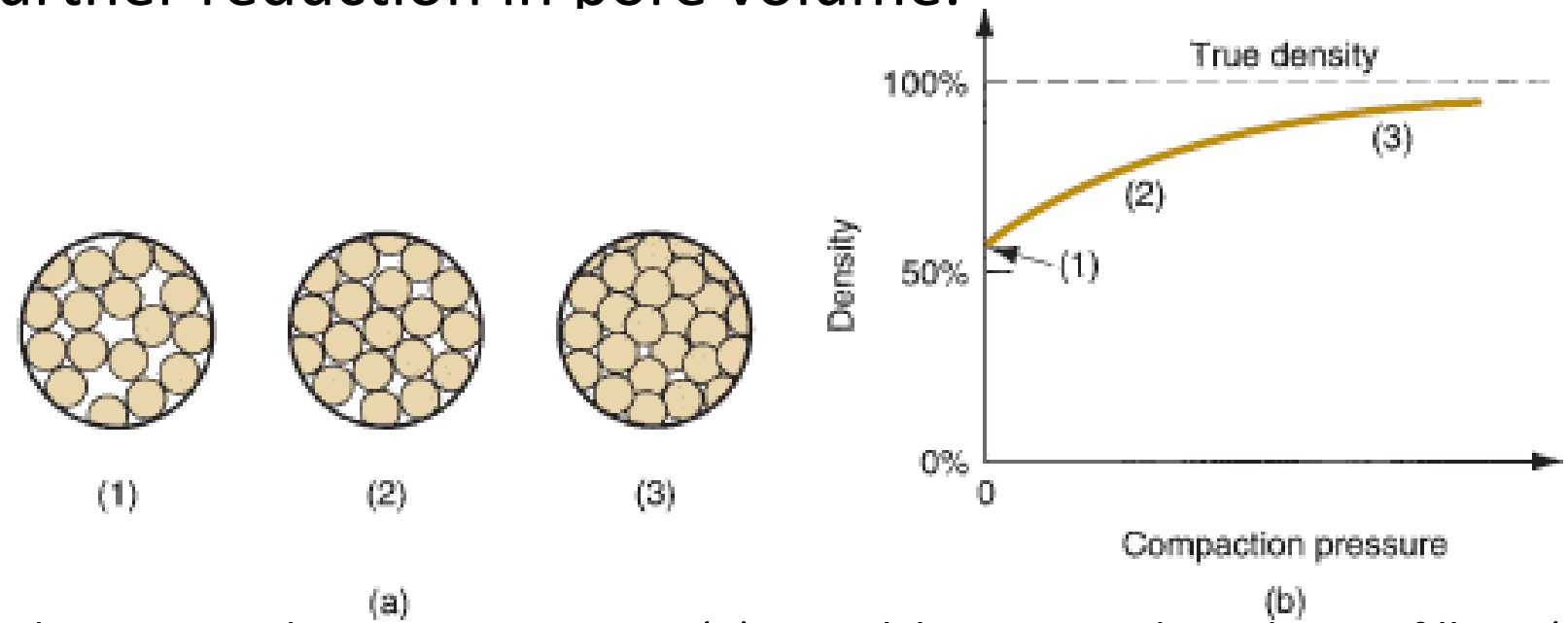
- Conventional method is pressing, in which opposing punches squeeze the powders contained in a die. The work part after pressing is called a green compact. The density of the compacted part is called the green density. It is greater than the starting bulk density.



1) Filling the die cavity with powder, done by automatic feed in production, (2) initial, and (3) final positions of upper and lower punches during compaction, and (4) ejection of part.

Compaction-The mechanism

- The applied pressure in compaction results initially in repacking of the powders into a more efficient arrangement, eliminating “bridges” formed during filling, reducing pore space, and increasing the number of contact points between particles.
- As pressure increases, the particles are plastically deformed, causing the inter-particle contact area to increase and additional particles make contact. This results in further reduction in pore volume.



(a) Effect of applied pressure during compaction (1) initial loose powders during filling (2) repacking, and (3) deformation of particles. (b) density of powders as a function of pressure.

Sintering

- After Pressing, the green compact lacks strength and hardness. It can crumble even under low stresses.

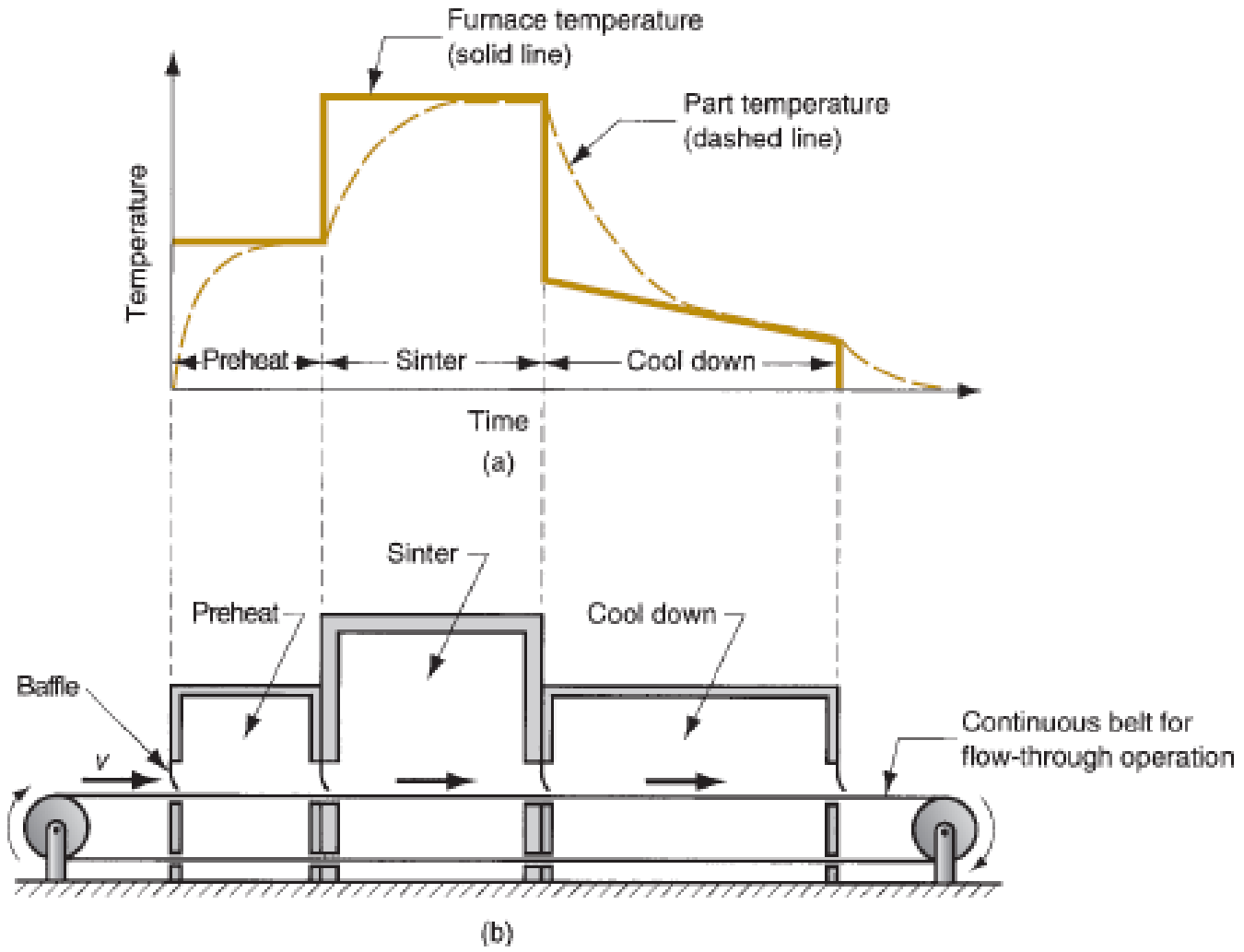
- Sintering is a heat treatment operation performed on the green compact to bond its metallic particles, thereby increasing its strength and hardness.

- The heat treatment is usually carried out at temperatures between 0.7 to 0.9 of the metal's melting point (absolute scale).

- The heat treatment consists of three steps, accomplished in three chambers in these continuous furnaces. The first is preheating, where lubricants and binders are vaporized.

Sintering

- The second stage is sinter, and finally, cooling. The typical heat treatment cycle is shown



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

Thank You !