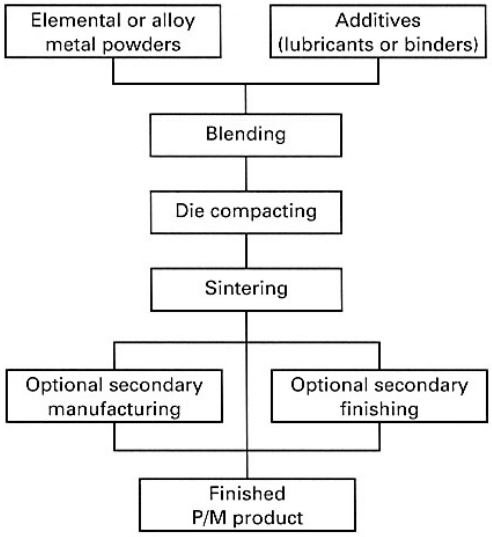
3.3 POWDER METALLURGY PROCESS

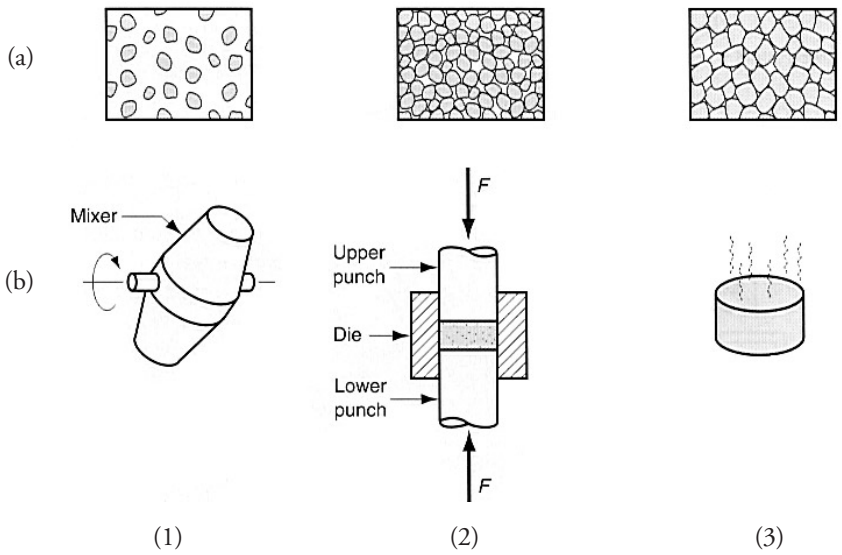
Overview

After the metallic powders have been produced and classified, the conventional P/M process sequence consists of three major steps: (1) *blending* and *mixing* of powders, (2) *compaction*, and (3) *sintering*, and a number of optional and finishing secondary operations.



Simplified flowchart illustrating the sequence of operations in powder metallurgy process

The condition of powders during the three primary P/M operations is shown in the figure:

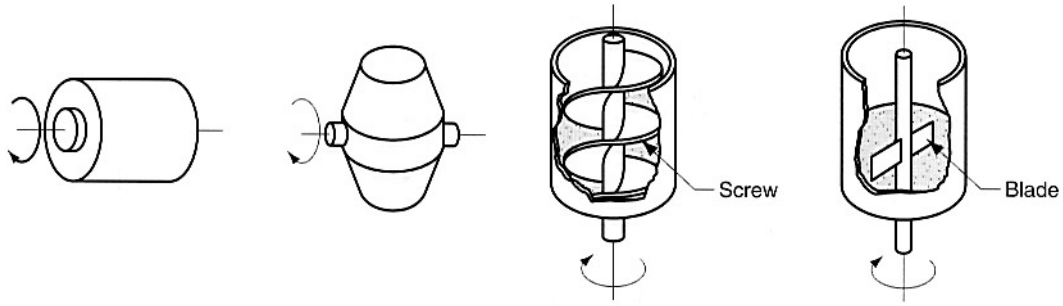


The conventional P/M process sequence: (1) blending, (2) compacting, and (3) sintering; (a) shows the condition of powders, and (b) shows the schematics of operation

Blending and mixing

Blending: mixing powder of the same chemical composition but different sizes
Mixing: combining powders of different chemistries

Blending and mixing are accomplished by mechanical means:



(a) (b) (c) (d)

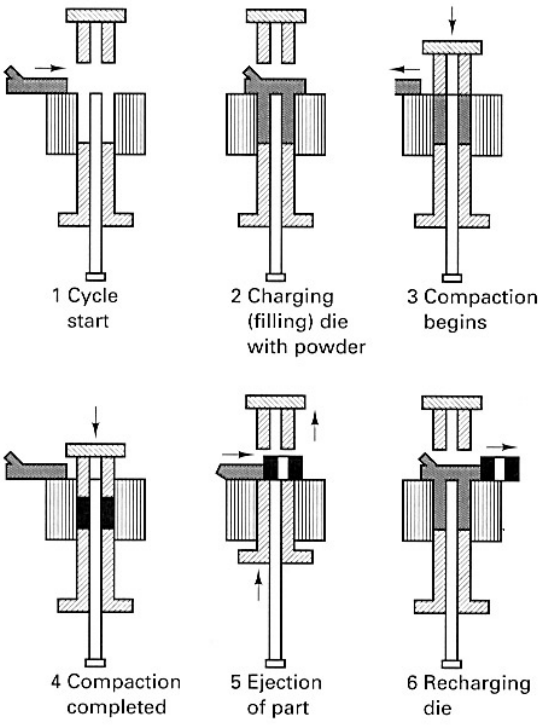
Several blending and mixing devices: (a) rotating drum, (b) rotating double cone, (c) screw mixer, (d) blade mixer

Except for powders, some other ingredients are usually added:

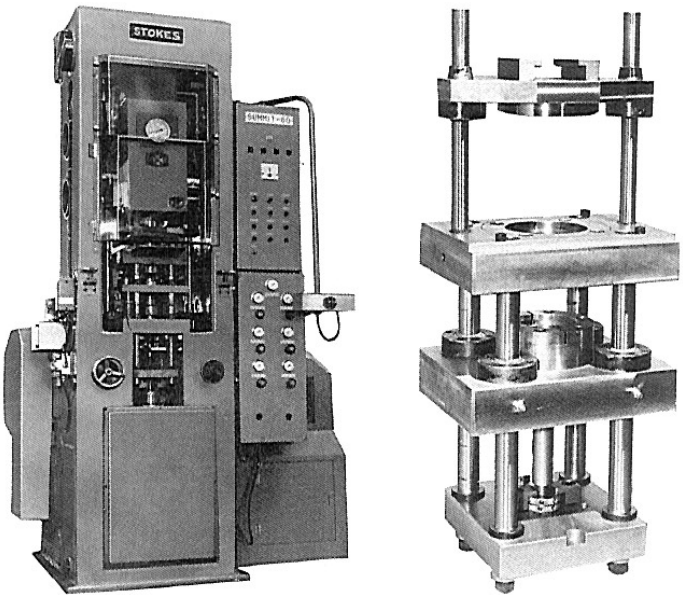
- *Lubricants*: to reduce the particles-die friction
- *Binders*: to achieve enough strength before sintering
- *Deflocculants*: to improve the flow characteristics during feeding

Compaction

Blended powers are pressed in dies under high pressure to form them into the required shape. The work part after compaction is called a *green compact* or simply a *green*, the word green meaning not yet fully processed.



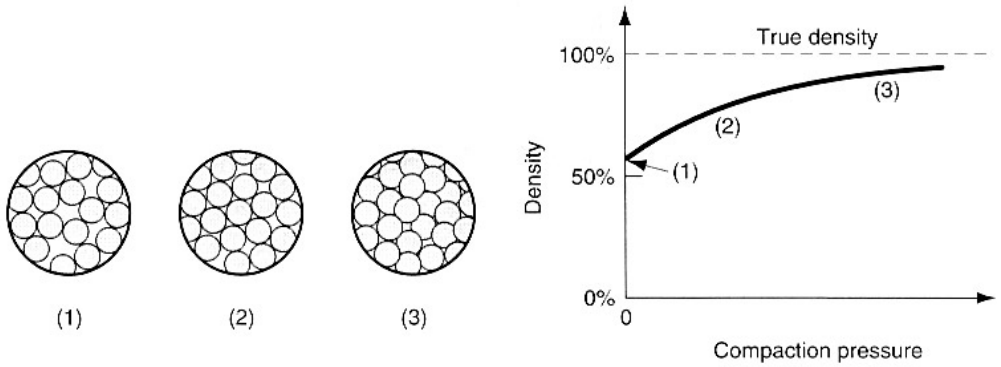
Typical steps in compaction



Typical press for the compaction of metallic powders. The removable die set (*right*) allows the machine to be producing parts with one die set while another is being fitted to produce a second part

Pressure and density distributions after compaction

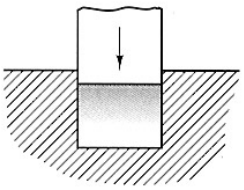
As a result of compaction, the density of the part, called the green density is much greater than the starting material density, but is not uniform in the green. The density and therefore mechanical properties vary across the part volume and depend on pressure in compaction:



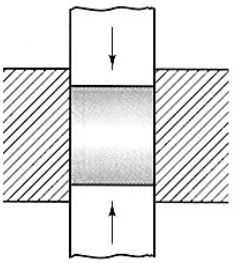
Effect of applied pressure during compaction: (1) initial loose powders after filling, (2) repacking, and (3) deformation of particles.

There are different ways to improve the density distribution:

❖ *Application of double acting press and two moving punches in conventional compaction*



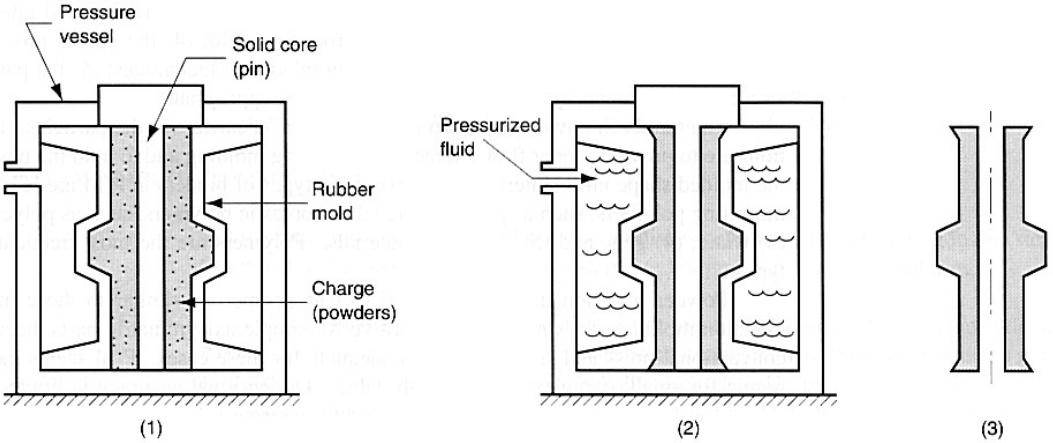
Compaction with a single punch, showing the resultant nonuniform density



Density distribution obtained with a double-acting press and two moving punches

❖ *Isostatic pressing*

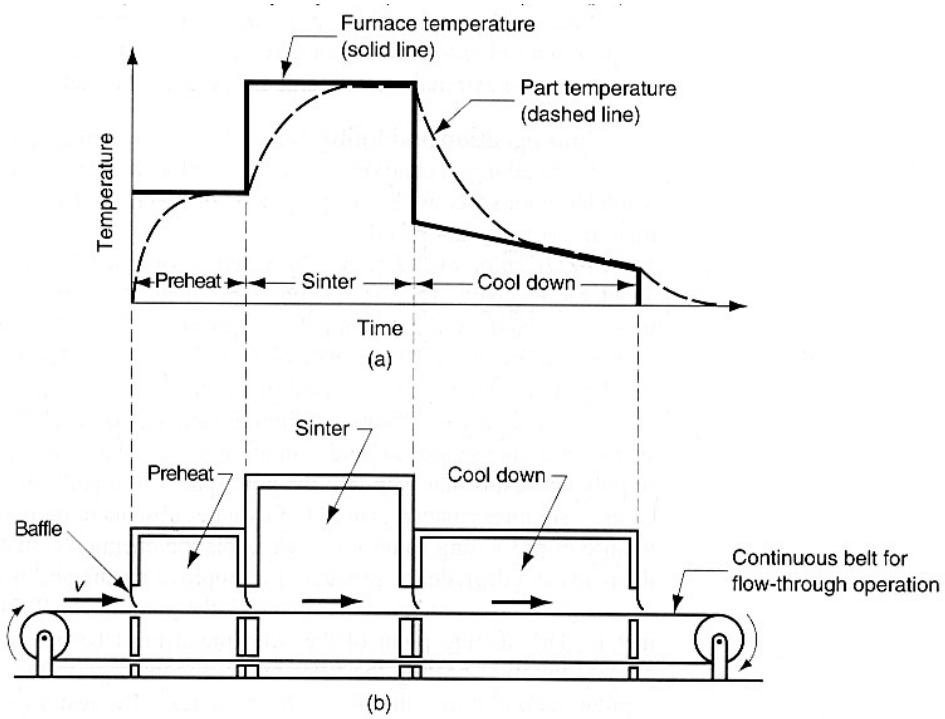
Pressure is applied from all directions against the powder, which is placed in a flexible mold:



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.

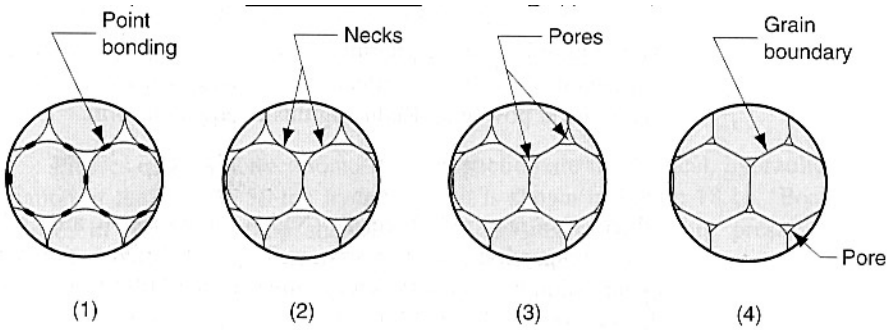
Sintering

Compressed metal powder is heated in a controlled-atmosphere furnace to a temperature below its melting point, but high enough to allow bounding of the particles:



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

The primary driving force for sintering is not the fusion of material, but formation and growth of bonds between the particles, as illustrated in a series of sketches showing on a microscopic scale the changes that occur during sintering of metallic powders.



Sintering on a microscopic scale. The illustration shows different stages in development of grain boundaries between particles.

Finishing operations

A number of secondary and finishing operations can be applied after sintering, some of them are:

- *Sizing*: cold pressing to improve dimensional accuracy
- *Coining*: cold pressing to press details into surface
- *Impregnation*: oil fills the pores of the part
- *Infiltration*: pores are filled with a molten metal
- *Heat treating, plating, painting*