Sample Parts made by P/M
Powder metallurgy is the name given to a process wherein fine metal powders are blended (mixed), pressed into a desired shape (compacted), and then heated (sintered) in a controlled atmosphere at a temperature below the melting point of the major constituent for sufficient time to bond the contacting surfaces of the particles and establish desired properties.

- 1930’s carbide tool materials
- 1960’s automobile parts
- 1980’s aircraft engine turbine parts
Some important properties of P/M are as follows.

- Used in mass production of small, intricate parts of high precision,
- No or little material is wasted,
- Usually no machining is required,
- Semiskilled labor is sufficient,
- Some unique properties, such as controlled degrees of porosity or built-in lubrication (made by impregnation process) can be obtained.
Controlled Degree of Porosity

Organic material particles burn and disappear during sintering. At their locations small empty volumes are left $\Rightarrow$ pores.

By controlling the sizes of the organic material particles, and by controlling their percentage in the powder mix, it becomes possible to have **controlled degree of porosity**.
Introduction

Basic Steps of P/M

1. Powder manufacture
   (Producing a fine metallic powder),

2. Blending
   (Mixing and preparing the powder for use),

3. Compacting
   (Pressing the powder into the desired shape),

4. Sintering (Heating the compacted product).

5. Secondary (Finishing) Operations (Optional)
The most commonly used methods for powder manufacture are:

1. Melt atomization,
2. Reduction of oxides or ores,
3. Electrolytic deposition from solutions or fused salts.

Lesser used processes are:

1. Pulverization or grinding,
2. Thermal decomposition of hydrides or carbonyls,
3. Condensation of metal vapors.
**Powder Manufacture**

**Melt Atomization**
- Ladle
- Tundish
- Atomizing water spray
- Atomizing chamber
- Metal particles

**Rotating Electrode Method**
- Inert Gas
- Vacuum
- Spindle
- Rotating Consumable Electrode
- Nonrotating Tungsten Electrode
- Collection Port
Powder Blending

Before compacting, powder is mixed and blended to,

1. Obtain uniform particle size distribution,
2. Mix powders of different materials,
3. Coat powder particles with lubricants.

- Can be done wet or dry.
- Water or solvent can be used for better mixing. Dusting is reduced, explosion hazards are lessened.
- Lubricants such as graphite or stearic acid are used to improve flow characteristics, to reduce die wear.
- Obtaining a uniform mix aids in the pressing operation and helps to assure uniformity throughout a run.
Loose powder is compressed and densified into a shape known as a green compact. Compacting is an important step, since,

1. Powder is formed into the desired shape,
2. It determines the density of the product,
3. It determines the uniformity of the density.
Flow characteristics of the powder is also very important, since it determines the flowing ability of the powder under pressure, which affects the speed of pressing and the final density.

The strength of a P/M product depends on the chemical composition of the powder and the final density.

The greater the density, the higher the strength is.

Pure metal and non-metal powders can be mixed.

Pre-alloyed powders can be used.

Precoated powders can be used.
The powder does not flow like a liquid, but develops an opposing force in the opposite direction of the applied force by means of friction between the particles themselves and the die surfaces.

Generally, it is not possible to transmit uniform pressures, and obtain uniform density throughout the compact.

Maximum pressure occurs near the plunger and decreases with the distance from the plunger. Maximum density also occurs near the plunger.
Compacting (Pressing)

- The thickness/width ratio should be kept below 2 whenever possible.

- Dies used for compacting are made from hardened tool steel. Their surfaces are highly polished. They should be heavy and strong enough to withstand high pressing pressures.
Compacting (Pressing)
Compacting (Pressing)

Initial conditions

After compaction

3/4 original volume or $1 \frac{1}{3} \times$ original density

1/2 original volume or $2 \times$ original density
Compacting (Pressing)

Single lower punch

Double lower punch
Other Compacting Techniques

**Powder Rolling**

- Loose powder
- Roll
- Compacted powder
- Hopper

**Powder Extrusion**

- Rotating screw
- Die
- Extruded profile
Sintering

- The compacts are subjected to elevated temperatures in a controlled atmosphere.
- Sintering strips contaminants from the surfaces of the powder particles, permitting diffusion bonding to occur and results in a single piece of material.
- Sintering is carried out below the melting point of the major constituent.
- Sintering atmospheres must be controlled carefully to prevent oxidation and combustion.
Sintering

Raw powder  Formed product

Sintered product
For many applications, P/M parts are ready for use as they come from the sintering oven. However, many products require one or more secondary operations to provide enhanced precision or special characteristics.

- Repressing, coining or sizing
- P/M Forging
- Impregnation
- Infiltration
Repressing, coining or sizing

A second pressing operation, known as repressing, coining or sizing, may be used to restore dimensional precision.

The part is placed in a die and subjected to pressures equal to or greater than the initial pressing pressure.

A small amount of plastic flow takes place, resulting in a very uniform product with respect to size and sharpness of detail.
If massive metal deformation occurs in the second pressing, the operation is known as P/M forging. Here P/M is used to produce preforms for forgings.
Impregnation - Infiltration

Impregnation refers to the forcing of oil or other liquid into the pores by either immersing the part in a bath and applying pressure or by a combination of vacuum-pressure process.

(e.g. Used to make oil-impregnated or self lubricating bearings.)

In infiltration, a molten metal of a lower melting point than the major constituent is forced into the product under pressure or absorbed by capillary action. Strength of the product is increased.
Properties of P/M Products

- In general, the strength properties of P/M products are inferior to pure wrought or cast metals. This is also true for alloys.

- As larger pressures are applied and secondary operations such as coining or P/M forging are employed to provide greater density, the strength properties of P/M products increase and be more nearly equal those of wrought materials.

(wrought: Beaten out or shaped with the hammer or other tools.)
Classification of P/M Products

1. **Porous products**, such as bearings, filters, and pressure or flow regulators.

2. **Products of complex shapes** that would require considerable machining when made by other processes. (e.g. Small gears, pawls, cams, small activating levers.)

3. **Products made from materials that are very difficult to machine**. (e.g. Tungsten carbide cutting tools.)

4. **Products where the combined properties of two metals, or of metals and nonmetals are desired**. (e.g. Motor generator brushes, electrical contacts, bearings.)
*** FORMING/powder metallurgy (SME/Wiley’s video)***