Unit 6: Powder Metallurgy

Powder metallurgy

- The **process of preparation and processing** the powdered **iron and non-ferrous metals** is called as **powder metallurgy**
- Powder metallurgy is the **process** whereby **metallic shapes are manufactured** from **metallic powders**.

This process involves a series of steps as follows

1. Manufacturing of the powder.
2. Powder is injected into a mould or die under pressure.
3. Then giving high temperature treatment - sintering to the object obtained, which is conducted at a temperature below the melting point of the basic metal.
4. The parts produced by this process **exhibit excellent properties** which **cannot be produced in any other way.**
5. Simple parts can be made to **required size** and **shape** with high precision, **without waste** and completely or almost **ready for installation.**
6. Powder metallurgy is becoming an increasing important tool in the fabrication of many products like production of **refractory metals, heat resistant materials** and **cutting tools of extreme hardness** and product produced by this process is porous **"self lubricating"** bearing.

Characteristics of powder for powder metallurgy

1. It should be heat resistant.
2. It should have proper chemical composition.
3. Size of the powder particles is to pass the powder through screen (sieves) having-a definite number of meshes.
4. The ratio of density of the compact to the apparent density of the powder should vary between 2:1 to 3:1.
5. The powder should have good plasticity.
6. Should have an ability to be cold pressed.
7. Should have excellent sintering ability.
8. Should have a good flowability.
9. The powder should be free from oxides and should have a clean surface.

Metals used

Most of the metals and alloys are used for the preparation of the powder.

The most common metals used are

- iron-base and copper-base materials.
- Titanium,
- chromium stainless steel,
- nickel metal powders etc.

Methods of manufacturing metal powder

1. Atomization
2. Electrolytic deposition
3. Reduction
4. Crushing and milling
5. Granulation
6. Shotting.

Atomisation

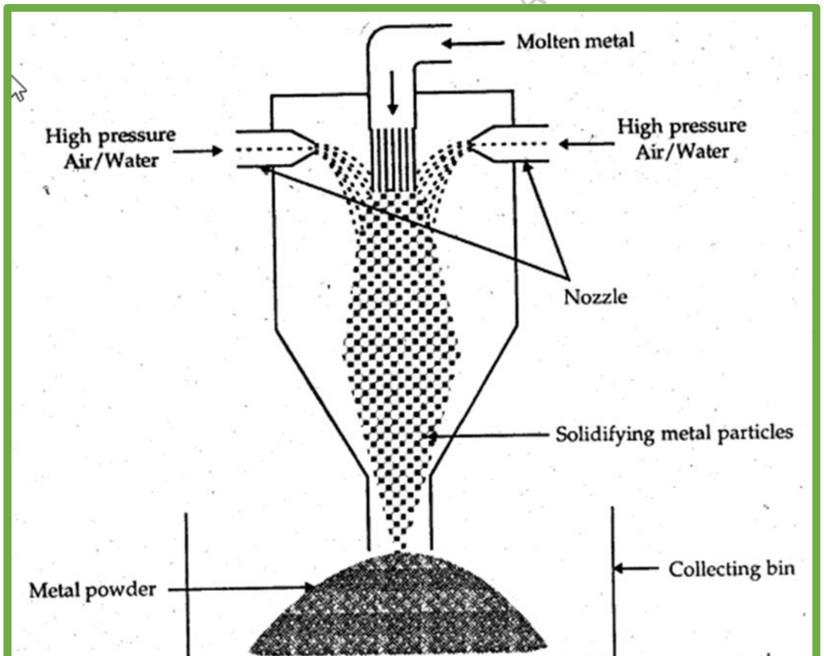


Fig. 6.1 : Atomization

- In this process, the molten metal is forced through a small nozzle into a stream of water or air and molten metal is broken up and solidified into small particles. The air is usually supplied at a pressure of about 2 to 310 N/m^2.
- The size of the particles manufactured depends upon the nozzle size, metal flow rate and its temperature. Oxidation can be prevented by the use of inert gas.
- This process can be used for metals like tin, zinc, lead, aluminum Cadmium etc. which have a low melting points. Alloy powders are also-produced by this process. After powder is made, it is washed before grinding.

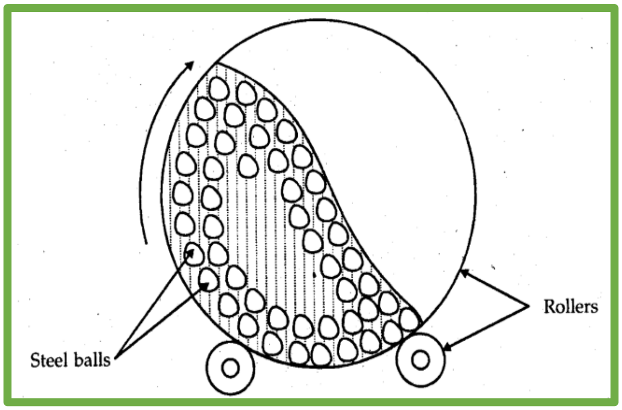
Electrolytic deposition

- This process is used for the manufacturing of copper, iron, tungsten, titanium, zinc, silver and even tin powders.
- In this Process the metal plates are placed in a tank containing an acid solution i.e., electrolyte. One metal plates act as anodes, while other metal acts as a cathodes.
- When high current is passed, metal powders are deposited electrolytically on the cathodes.
- The cathodes are removed from the tank and rinsed to remove the electrolyte solution and then dried.
- After a drying period, the deposited is scraped off and pulverized, to produce powder of the desired size.

Reduction

- In this method, the metal powders are obtained by **reducing refined ores** or oxides in a **current of hydrogen gas.**
- This process is used for **only some** metals like **tungsten, nickel, cobalt**, etc., having high melting points. The **pulverized tungsten oxide** is heated in **current of hydrogen**, the hydrogen **reduces the oxide** from the tungsten oxide to metallic **tungsten powder.**
- Pure **iron powder** is produced by **reducing, iron chloride** in a current of hydrogen.

Crushing



- The metal powder obtained by atomization or Electrolytic deposition are poured into the ball mill, and steel balls are also placed in the roller.
- The roller is rotated with slow speed.
- The impinging action by a balls over the powder produces the fine powder of required size

Granulation

Granulation results in course particles which may be further milled and it is principally used for magnesium powders.

Powder Metallurgy Processes

Primary processes

1. Blending or mixing
2. Briquetting or compacting
3. Presintering
4. Sintering

Secondary processes

1. Sizing
2. Coining
3. Machining
4. Impregnation
5. Infiltration
6. Plating
7. Heat treatment

Shotting

- Shotting is the operation of powdering the molten metal by pouring through a screen and cooling it by dropping it into water.
- Spherical or pearl-shaped particles are obtained by this process.
- Shotting is mainly used for metals like aluminium, lead and zinc

Blending (Mixing of powders)

- It is the first step in the forming of powder metal parts in which powders are mixed properly.
- The blend of powders determines the different properties that can be obtained. Many combinations of metals and metals with ceramics or other melted alloys can be used. These materials have high heat resistance, frictional properties, heavy weight and hardness which are not at all possible by any other methods.
- The main purpose of blending is to produce uniformity of particle size and shape throughout the large amount of powder.
- In blending, the various powders are weighed in the correct proportions and mixed. Lubricants are also added to give green strength and to facilitate pressing.

Compacting

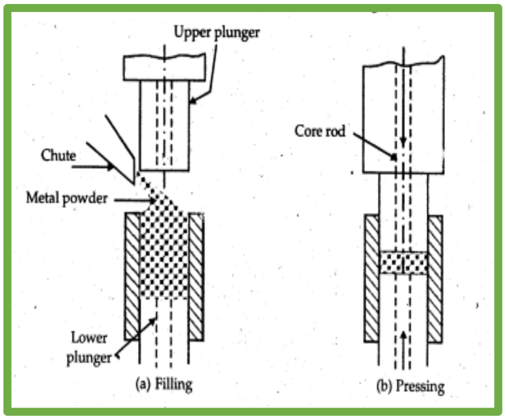
- The compacting is also called as brequetting or compressing.
- It is the process of converting the loose powder into a green compact of accurately defined size and shape.
- At this condition it is fairly fragile and it cannot be handled.
- The compacting is carried out at the room temperature in a die setup on press. Metal powder is poured in the cavity and levelled off. The punches operate both from top and bottom of the die and applies the pressure simultaneously.
- The powder is compressed to the desired shape to 1/ 3rd of its original volume.

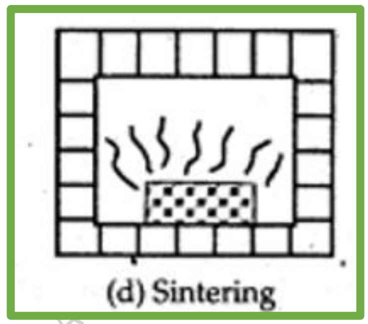
Pre-sintering

- Presintering is the process of heating the green compact to a temperature below the sintering temperature.
- The presintering is done to remove the lubricants and binders, added while blending and to increase the strength of the compact.
- All metals do not require pre-sintering, but some metals like tungsten carbide are easily machined after pre-sintering and they very after sintering such that they cannot be machined

Sintering

- Sintering : Sintering is the process of heating the powder compacts in furnace to a temperature close to the melting point of at least one of the major constituents in a controlled atmosphere.
- It may also be carried out under protective gas normally hydrogen or in a vacuum if the material tends to react with the protective gas.
- The heating causes the metal particles to sinter i.e., cement the particles together in a cellular structure.





- Sintering is performed to get final strength and hardness required in a finished product.
- The important governing variables of sintering are temperature, time and sintering atmosphere.
- During sintering workpiece dimensions may change i.e., it may expand or contract.
- Bronze tends to expand and iron and brass tends to contract.

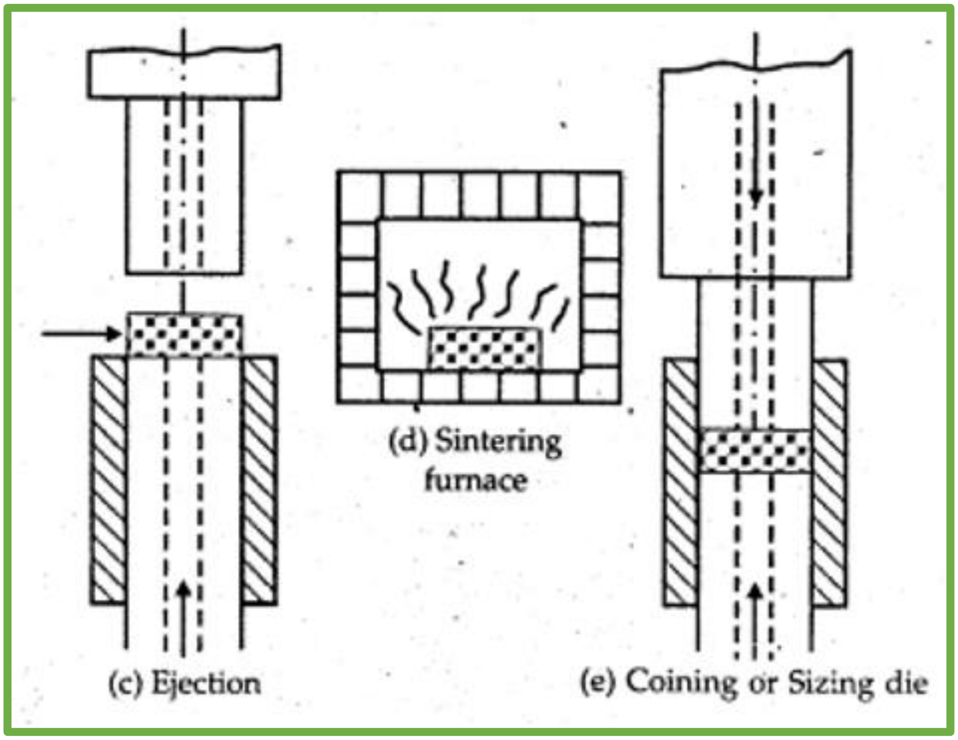
Objectives of sintering

1. To increase the **strength** of final product.
2. To increase the **hardness** required.
3. To increase **electrical conductivity.**
4. To increase the **density** and **durability.**
5. To give the **dimensional stability.**

Secondary operations of powder metallurgy

- When a desired **surface finish** and **tolerance** of the metal structure **can not be obtained by primary processes**, then the **additional secondary operations** have to be carried out after the sintering

Sizing and coining



- Sizing operation can be done by machining or may be done by a punch and die set-up on a press as shown in figure
- Sizing produces better **dimensional accuracy** with significant **increase in its density**.
- Coining on other hand significantly **increase the density** and at the same time also **improves the mechanical properties**, surface finish and dimensional accuracy.

Machining

- Machining : Sometimes sintered parts are finished by conventional machining when high degree of accuracy is required.

Impregnation

- Impregnation : When self lubrication properties are required, the sintered parts are impregnated or saturated with oil, grease, wax or other lubricating materials.
- The lubricant is retained in the part by the capillary action, until external pressure or heat of friction draws it to the surface

Infiltration

- Infiltration : Porosity of sintered products can be improved by the process called infiltration, in which the pores are filled with a lower melting point metal by capillary action.
- Ex : Copper is used as infiltrant to strengthen the iron and steel by passing the compact with the infiltrant laid on top.

Plating

Plating is done for two objectives –

- one for pleasing appearance and
- second one is protection from corrosion. In powdered metal parts, porosity must be eliminated before the part is plated. After the elimination of porosity plating can be done by using regular procedure.)

Heat treatment

- Heat treatment : The heat treatment is done on powder metal parts to **improve grain structure, strength and hardness**.
- Heat treatment of sintered part will be done by using regular procedure with the selection of proper required heat treatment process.

Products or uses

1. To produce porous products porous oil impregnated bearings.
2. High capacity electric accumulator plates.
3. Porous filters.
4. To produce Babbitt bearings for automobiles.
5. To produce oil pump gears for automobiles.
6. Used for production of cutting tools, wire drawing dies and deep drawing dies.
7. To produce refractory metal composites, e.g., tungsten, molybdenum, tantalum and platinum
8. For manufacturing the tungsten wires for filaments in lamp industry.
9. Diamond impregnated tools are produced by mixture of iron powder and diamond dust.
10. To produce electrical contact materials, e.g., circuit breakers, relays and resistance welding electrodes.
11. For the production of magnetic materials, e.g., pole pieces for d.c. motors and cores for high frequency inductance.
12. Parts of cars, aircraft, gas turbines, electric clocks, etc.
13. Parts of vacuum cleaners, refrigerators.
14. Part of guns, sewing machines etc.
15. Clutch facings and brake linings.
16. Motor brushes.
17. Metal coatings, magnets.

Advantages of powder metallurgy

1. The parts can be produced clean, bright and ready for use.
2. Composition of the product can be controlled effectively.
3. Articles of any intricate shape can be manufactured.
4. Close dimensional tolerance can be achieved.
5. Machining operation is almost eliminated.
6. Parts have excellent finish and high dimensional accuracy.
7. There is overall economy as material wastage is negligible
8. Metals and non-metals can be mixed in any proportion.
9. A wide range of properties such as porosity, density, etc., can be achieved
10. High production rate can be achieved.
11. Reduced production time.
12. Highly skilled labour is not required.
13. Saving in material through reduced wastage.
14. Super-hard cutting tools, bits and refractory materials which can never be made by any other method can be produced.
15. Diamond impregnated tools for cutting glass and tungsten carbides can be produced only by this process.
16. Wide range of parts with special electrical and magnetic properties can be produced

Disadvantages of powder metallurgy

1. Size of the parts is limited as large presses are needed to get required compressing pressure.
2. The equipment used for the operation are costly.
3. Impossibility of having completely dense product.
4. Pressure upto 100 tonnes capacity are used even for small products.
5. Metal powders are expensive and in some cases difficult to store.
6. Some powders may present explosion hazards.
7. Dies used must be of high accuracy and capable of withstanding high temperature and pressure.
8. Parts produced have poor ductility.
9. No flow of metal particles, hence it is difficult to obtain intricate shape.
10. High tooling cost.
11. Difficulty of sintering low melting powder.