Unit Six: Powder Metallurgy

1. Introduction

Powder metallurgy is used for manufacturing products or articles from powdered metals by placing these powders in molds and are compacting the same using heavy compressive force. Typical examples of such article or products are grinding wheels, filament wire, magnets, welding rods, tungsten carbide cutting tools, self-lubricating bearings electrical contacts and turbines blades having high temperature strength.

The manufacture of parts by powder metallurgy process involves the manufacture of powders, blending, compacting, sintering and several secondary operations such as sizing, machining, infiltration, plating, and heat treatment.

The compressed articles are then heated to temperatures much below their melting points to bind the particles together and improve their strength and other properties. Few non-metallic materials can also be added to the metallic powders to provide adequate bond or impart some the needed properties.

The products made through this process are very costly on account of the high cost of metal powders as well as of the dies used. The powders of almost all metals and a large quantity of alloys, and nonmetals may be used.

2. POWDER METALLURGY PROCESS

The powder metallurgy process consists of the following basic steps:

1. Formation of metallic powders.
2. Mixing or blending of the metallic powders in required proportions.
3. Compressing and compacting the powders into desired shapes and sizes in form of articles.
4. Sintering the compacted articles in a controlled furnace atmosphere.
5. Subjecting the sintered articles to secondary processing if needed so.

3. ADVANTAGES OF POWDER METALLURGY

1. The processes of powder metallurgy are quite and clean.
2. Articles of any complicated shape can be manufactured.
3. The dimensional accuracy and surface finish obtainable are much better for many applications and hence machining can be eliminated.
4. No material is being wasted as scrap and the process makes utilizes full raw material.
5. High production rates can be easily achieved.
6. This process facilitates production of many such parts, which cannot be produced through other methods, such as sintered carbides and self-lubricating bearings.
7. The components produced by this process are highly pure and bears longer life.
8. It enables production of parts from such alloys, which possess poor cast ability.

4. LIMITATIONS OF POWDER METALLURGY

1. Powder metallurgy process is not economical for small-scale production.
2. The cost of tool and die of powder metallurgical set-up is relatively high.
3. Articles made by powder metallurgy in most cases do not have as good physical properties as wrought or cast parts.
4. The process is not found economical for small-scale production.
5. It is not easy to convert brass, bronze and a number of steels into powdered form.

5. Production of Metal Powders

The commonly used powder making processes are given as under

1. **Atomization:** In this process, the molten metal is forced through an orifice and as it emerges, a high-pressure stream of gas or liquid impinges on it causing it to atomize into fine particles. The inert gas is then employed to improve the purity of the powder. It is used mostly for low melting point metals such as tin, zinc, lead, aluminum, cadmium etc.

2. **Chemical Reduction Process**: In this process, the compounds of metals such as iron oxides are reduced with CO or H2 at temperatures below the melting point of the metal in an atmosphere-controlled furnace.

$$Fe_3O_4 + 4C = 3Fe + 4CO$$

$$Fe_3O_4 + 4CO = 3Fe + 4CO2$$

Copper powder is also produced by the same procedure by heating copper oxide in a stream of hydrogen.

$$Cu_2 + H_2 = 2Cu + H_2O$$

Powders of W (Tungsten), Mo (Molybdenum), Ni (Nickle) and CO can easily be produced or manufactured by reduction process because it is convenient, economical, and flexible technique and perhaps the largest volume of metallurgy powders is made by the process of oxide reduction.

3. **Electrolytic Process:** It is quite like electroplating and is principally employed to produce extremely pure, powders of copper and iron. For making copper powder, copper plates are placed as anodes in a tank of electrolyte, whereas aluminum plates are placed into the electrolyte to act as cathodes.
4. **Crushing Process**: The crushing process requires equipment such as crushers, or gyratory crushes. Various ferrous and non-ferrous alloys can be heat-treated to obtain a sufficiently brittle material which can be easily crushed into powder form.
5. **Milling Process**: It is commonly used for production of metallic powder. It is carried out by using equipment such as ball mill, impact mill, eddy mill, disk mill, vortex mill, etc. Milling and grinding process can easily be employed for brittle, tougher, malleable, ductile, and harder metals to pulverize them.
6. **Condensation of Metal Powders**: This process can be applied in case of metals, such as Zn, Cd and Mg, which can be boiled, and the vapors are condensed in a powder form. Generally, a rod of metal say Zn is fed into a high temperature flame and vaporized droplets of metal are then allowed to condense on to a cool surface of a material to which they will not adhere.

6. Characteristic of Metal Powders

6.1. Powder particle size

Particle size of metal powder is expressed by the diameter for spherical shaped particles and by the average diameter for non-spherical particle as determined by

sieving method or microscopic examination. Metal powders used in powder metallurgy usually vary in size from 20 to 200 microns. Particle size influences density/porosity of the compact, mold strength, permeability, flow and mixing characteristics.

6.2. Particle shape

There are various shapes of metal powders namely spherical, sub-rounded, rounded, angular, sub-angular, flakes etc. Particle's shape influences the packing and flow characteristics of the powders.

6.3. Chemical composition

Chemical composition of metallic powder implies the type and percentage of alloying elements and impurities. It usually determines the particle hardness and compressibility. The chemical composition of a powder can be determined by chemical analysis methods.

6.4. Particle microstructure

Particle microstructure reveals various phases, inclusions, and internal porosity.

6.5. Apparent density

Apparent density is defined as the weight, of a loosely heated quantity of powder necessary to fill a given die cavity completely.

6.6. Flow characteristics

Flow-ability of metal powders is most important in cases where moulds have to be filled quickly. Metal powders with good flow characteristics fill a mould cavity uniformly.

QUESTIONS

1. What do you understand by powder metallurgy? What are the main stages of powder metallurgy process?
2. Explain the objectives of powder compaction and list important products of powder metallurgy.
3. Describe the atomization process of making powder in detail.

4. What are the effects of sintering on the powder compact produced by pressing?
5. Describe the process of blending, compacting, and sintering in detail.
6. What are the effects of sintering on the powder compact produced by pressing?
7. Name the products of powder metallurgy.
8. List the advantages, dis-advantages of powder metallurgy process.

YouTube: https://youtu.be/-5p9smqlGX8