7.6 Powder metallurgy

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, and 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, profiteering, sintering and a number of secondary operations such as sizing, coining, machining, impregnation, 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. The application of powder metallurgy process is economically feasible only for high mass production. Parts made by powder metallurgy process exhibit properties, which cannot be produced by conventional methods.

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.

7.6.1 Production of Metal Powders

Metallic powders possessing different properties can be produced easily. The most commonly used powders are copper-base and iron-base materials. But titanium, chromium, nickel, and stainless steel metal powders are also used. In the majority of powders, the size of the particle varies from several microns to 0.5 mm. The most common particle size of powders falls into a range of 10 to 40 microns. The chemical and physical properties of metals depend upon the size and shape of the powder particles. There are various methods of manufacturing powders. The commonly used powder making processes are given as under.

1. Atomization
2. Electrolytic process
4. Condensation of metal vapors
5. Hydride and carbonyl processes.
6. Chemical reduction

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 in order to improve the purity of the powder. It is used mostly for low melting point metals such as tin, zinc, lead, aluminium, cadmium etc., because of the corrosive action of the metal on the orifice (or nozzle) at high temperatures. Alloy powders are also produced by this method.

2. Electrolytic Process
Electrolysis process is quite similar to electroplating and is principally employed for the production of extremely pure, powders of copper and iron. For making copper powder, copper plates are placed as anodes in a tank of electrolyte, whereas, aluminium plates are placed in to the electrolyte to act as cathodes. High amperage produces a powdery deposit of anode metal on the cathodes. After a definite time period, the cathode plates are taken out from the tank, rinsed to remove electrolyte and are then dried. The copper deposited on the cathode plates is then scraped off and pulverized to produce copper powder of the desired grain size. The electrolytic powder is quite resistant to oxidation.

3. 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. This method is not highly suitable for large scale production of powder.

4. Hydride and Carbonyl Processes
High hardness oriented metals such as tantalum, niobium and zirconium are made to combine with hydrogen form hydrides that are stable at room temperature, but to begin to dissociate into hydrogen and the pure metal when heated to about 350°C. Similarly nickel and iron can be made to combine with CO to form volatile carbonyls. The carbonyl vapor is then decomposed in a cooled chamber so that almost spherical particles of very pure metals are deposited.

5. Chemical Reduction Process
In this process, the compounds of metals such as iron oxides are reduced with CO or H_2 at temperatures below the melting point of the metal in an atmosphere controlled furnace. The reduced product is then crushed and ground. Iron powder is produced in this way

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

$$Fe_3O_4 + 4CO = 3Fe + 4CO_2$$

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, Mo, Ni 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.

7.6.2 Mixing or Blending of Metallic Powders
After the formation of metallic powders, proper mixing or blending of powders is the first step in the forming of powder metal parts. The mixing is being carried out either wet or dry using an efficient mixer to produce a homogeneous mixture.

7.6.3 Compacting of Powder
Compacting is the technique of converting loose powder in to compact accurately defined shape and size. This is carried out at room temperature in a die on press machine. The press used for compacting may be either mechanically or hydraulically operated. The die consists of a cavity of

the shape of the desired part. Metal powder is poured in the die cavity and pressure is applied using punches, which usually work from the top and bottom of the die. Dies are usually made of high grade steel, but sometimes carbide dies are used for long production runs. In compacting process, the pressure applied should be uniform and applied simultaneously from above and below. The pressure applied should be high enough to produce cold welding of the powder. Cold welding imparts a green strength, which holds the parts together and allows them to be handled. The metal parts obtained after compacting are not strong and dense. To improve these properties, the parts should be sintered.

7.6.4 Sintering

Sintering is the process of heating of compacted products in a furnace to below the melting point of at least one of the major constituents under a controlled atmosphere. The sintering temperature and time vary with the following factors-

1. Type of metal powder
2. Compressive load used, and
3. Strength requirements of the finished parts.

In the sintering furnace, the metal parts are gradually heated and soaked at the required temperature. During this gradually heating process, powders bond themselves into coherent bodies. Sintering results in strengthening of fragile green compacts produced by the pressing operation. It also increases electrical conductivity, density and ductility of the powder metal parts.

7.6.5 Finishing Operations

Some powder metal parts may be used in the sintered condition while in some other cases additional secondary operations have to be performed to get the desired surface finish, close tolerance etc. The secondary operations may be have following types- Polishing, Surface treatments to protect against corrosion, forging etc.

- **ADVANTAGES OF POWDER METALLURGY**

1) The processes of powder metallurgy are quite and clean.
2) Articles of any intricate or 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) Unlike casting, press forming machining, no material is being wasted as scrap and the process makes utilizes full raw material
5) Hard to process materials such as diamond can be converted into usable components and tools through this process.
6) High production rates can be easily achieved.