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Department of Aerospace Engineering
19AST202 AIRCRAFT PRODUCTION TECHNOLOGY

[redacted]

- Powder Metallurgy
- Powder Metallurgy Processes
- Applications of Powder Metallurgy

Powder Metallurgy

Powder Metallurgy is one such manufacturing process which makes use of metals in their powdered form for making a variety of products. In simple terms it is a metal processing technology in which parts are made from metal powders. This process involves the following steps:

1. Production of metal powders;
2. Blending together the powders of the same or different metals;
3. Compacting the powder mixture in a metallic die to form a compact; and
4. Sintering to allow the development of a bond between the particles of metal powders to obtain a hard, strong and tough product.

The most commonly used metal powders are made from iron, copper, tin, aluminium and nickel metals. Powder metallurgy technique is generally used for making small articles like ball pens, cutting tools, bushings and gears. This process is suitable for mass production of small, intricate and extremely high-quality metal components that need to be manufactured with precision so there is little or no need for further machining. It is often used where desired properties and characteristics are difficult to obtain by any other method. Figure 11.1 shows the outline of operations involved in making a powder metallurgy product.

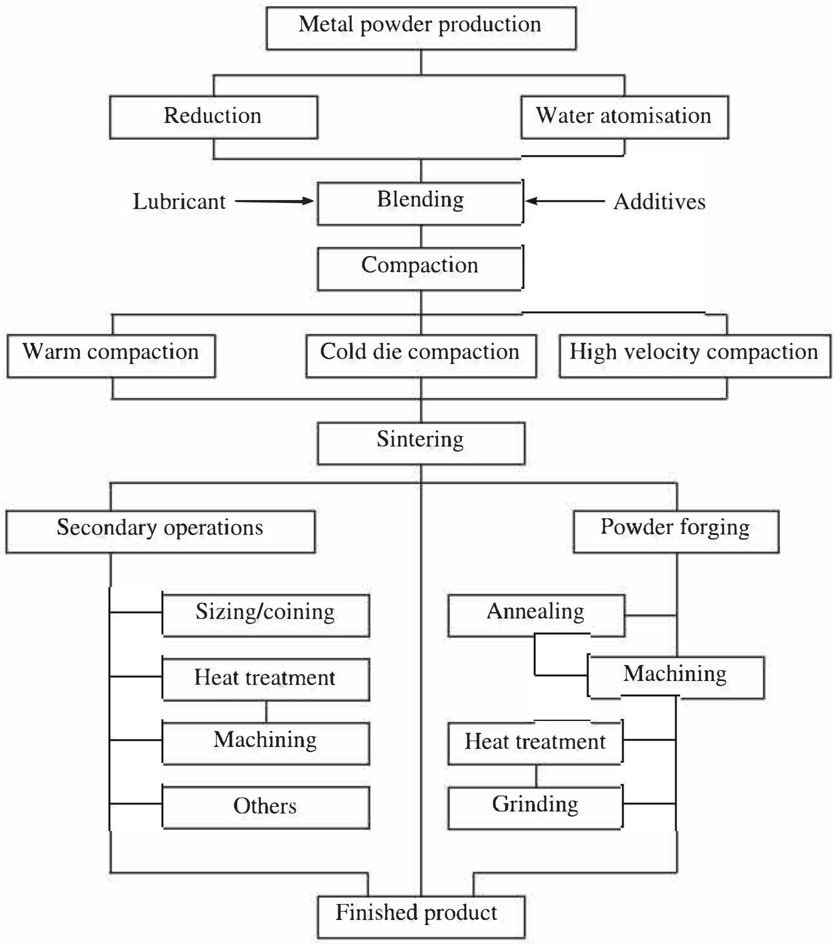


Figure Outline of operations involved in making a powder metallurgy product.

Powder Metallurgy Processes

The powder metallurgy processes consist of the two process groups:

1. **Primary Operations**

   These cover the following main phases:
   (a) Production of metal powders;
   (b) Blending or mixing of metal powders;
   (c) Compaction of powders into green compacts; and
   (d) Sintering of green compacts.

2. **Secondary Operations**

   These operations are performed after sintering to improve the strength, density and function behaviour of products. These are as follows:

(a) Sizing
(b) Impregnation
(c) Infiltration
(d) Machining
(e) Plating

Primary Operations

Production of metal powders

Metal powders are available in large varieties with infinite range of properties. Today not only iron, carbon steel, alloy steel, stainless steels and non-ferrous metals, such as brass, bronze, aluminium, copper and nickel are available in powder form, but also the high melting point refractory metals, such as tungsten, molybdenum and tantalum, and other precious metals, such as silver, gold and platinum.

Properties of powder metallurgy of products depends upon the properties of powder particles, such as particle shape, particle size, size distribution, shape, surface condition and physical characteristics of the base metal of the powder.

The following methods are commonly used for producing powders:

1. Atomisation
2. Reduction of metal oxides
3. Electrolytic deposition
4. Pulverisation (mechanical communication)

Atomisation The process of *Atomisation* consists of forcing molten metal through a small orifice to reduce it into a thin stream of liquid metal which is broken up further into small particles of metal by subjecting it to a jet of compressed air or stream, or some inert gas (Figure 11.2). This instantaneously solidifies the stream of metal in the form of small particles. The size of powder is controlled by the orifice design and gas pressure.

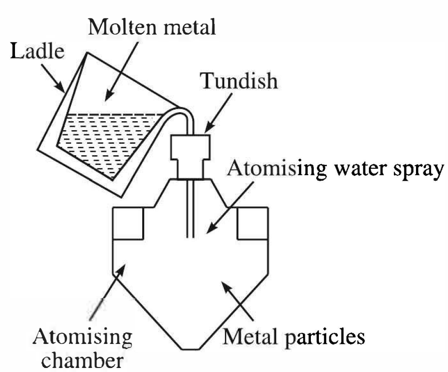
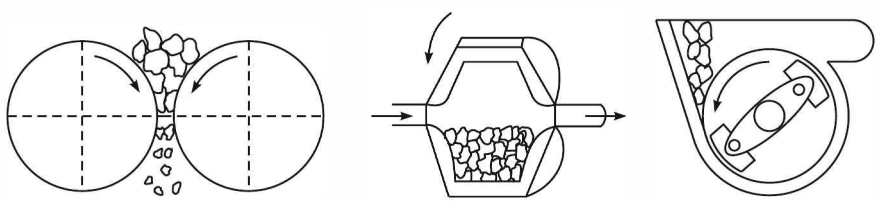


Figure Atomisation.

Reduction of metal oxide: The reduction of metal oxides (removal of gas) is done by using gases, such as hydrogen and carbon monoxide, as reducing agents. The powder thus obtained has uniformly sized spherical or angular shapes.

Electrolytic depositions: The process is similar to electroplating in which one metal plate acts as the anode and the other metal plate acts as the cathode. When high current is passed through the electrolyte the metal powder is deposited on the cathode. After the process is over it is washed with water, dried, and then it is scrapped off and pulverised to produce the powder of desired grain size. This process produces the powders of iron, copper, nickel, tin cadmium, antimony, zinc and lead.

Pulverisation (Mechanical comminution): These are mechanical methods and generally the cheapest of the powder making processes. These involve the use of mechanical forces like shear, compressive and impact to facilitate particle size reduction of bulk material. Pulverisation involves crushing, milling in a ball mill, or grinding metals into small particles. Figure 11.3 shows a few mechanical pulverisation methods used in production of metal powder.



(a) Roll crushing (b) Ball milling (c) Hammer milling

Figure Methods of mechanical comminution.

Blending or mixing of metal powders

Blending (mixing) powders is the second step in powder metallurgy processing. It is carried at for the following purposes:

1. Powders made by various processes have different sizes and shapes; it is done to obtain a uniform distribution of particle sizes.
2. Mixing of powders of metals and non-metals.
3. Mixing of lubricants with metal powders to modify metal to powder interaction during compaction. Lubricants such as graphite, stearic acid or zinc stearate are used to improve flowability of metal powders by reducing friction between the die wall and powder, as also between particles of the powders themselves.

Figure shows the schematics of some of the blending or mixing process equipment.

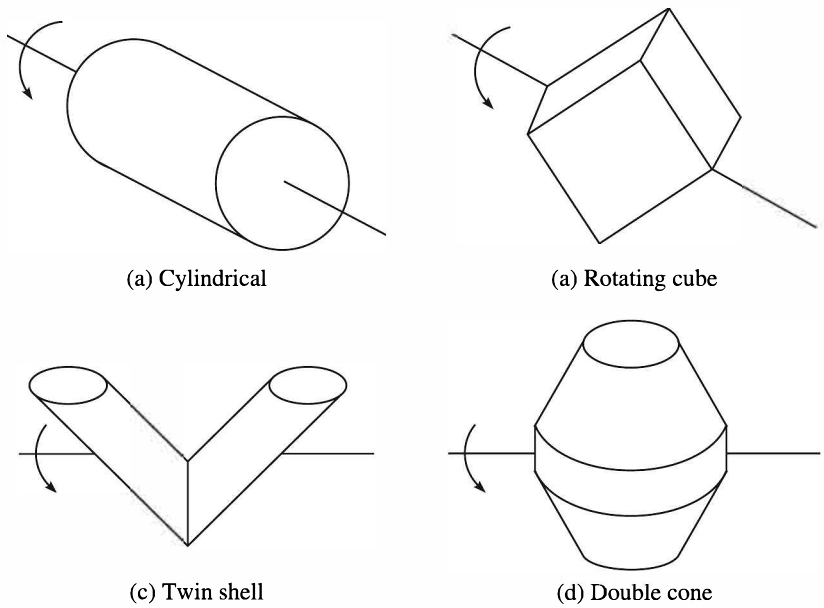


Figure Blending or mixing equipment.

Compaction of metal powders

Compaction is an important step in powder processing as it enables the forming of loose metal powders into required shapes with sufficient strength to withstand till sintering is completed. After blending, the powder is placed in acetic and compacted by pushing a punch under pressure. The dies are usually made of tungsten carbide to reduce wear of dies and to reduce the compacting force. The pressed powder is known as a *Green Compact*. The powder must flow easily to feed properly into the die cavity. Pressing is generally done at room temperature although it can be carried out at elevated temperature.

Sintering of green compact

Sintering is the process whereby green compacts are heated in a controlled atmosphere furnace to a temperature below the melting point, but sufficiently high to allow bonding of the individual particles. Sintering raises the ultimate strength of the product. It results in diffusion bonding of particles. Table 11.1 gives the sintering temperature and process time for different materials.

Secondary Operations

Many powder metallurgy parts are used in sintered conditions; other processes may require some secondary operations, like sizing, impregnation, infiltration and machining plating. These are as follows:

Table Sintering temperature and time for various metals

Material	Temperature (°C)	Time (min.)
Copper, Brass and Bronze	775–910	10–50
Iron and Graphite	1000–1170	4–40
Nickle	1000–1150	30–45
Stainless steel	1100–1300	30–60
Alnico alloys	1200–1300	120–150
Ferrites	1200–1500	10–600
Tungsten Carbide	1430–1500	20–30
Molybdenum	2050	120
Tungsten	2350	480
Tantalum	2400	480

Sizing

Sizing is used to improve product strength and finishing. It consists of repressing of a sintered product in a die to take care of distortion.

Impregnation

Impregnation provides self-lubricating properties in which sintered parts are impregnated with grease or oil by heating them to about 100°C in oil for 10 minutes to 15 minutes.

Infiltration

The objective of *Infiltration* is to increase strength, density and hardness. It is done by placing a slug of copper alloy on top of the powder metallurgy parts during the sintering process.

Machining

Machining improves the finishing of sintered products by correcting their size and shape with the utilisation of machine, which is not possible through previous operations.

Plating

Plating is done to refine the appearance of the product to improve the resistance to wear and corrosion.

Applications of Powder Metallurgy

Powder metallurgy products have a large number of applications. Some of them are given as follows:

1. ***Porous products:*** Any degree of porosity can be obtained in powder metallurgy products. Some examples of porous products are bearing, sound dampers, filters and flow regulators.
2. ***Machine components:*** Machine components, such as connecting rods, cams, connecting rods of automobiles, piston rod valve guides and other components of IC engines are made by powder metallurgy process.
3. ***Cemented carbides:*** Cemented carbides' tools are made by powder metallurgy process.
4. ***Tungsten filament:*** Tungsten powder is pressed into bars and sintered, and drawn through tungsten carbide dies to make filament wires.
5. ***Combination of metal and non-metal:*** Various combinations of metals and non-metals are used for various applications, and they made by powder metallurgy process. They are clutch plates and brake lining, copper-graphite bearing, etc.

Advantages of Powder Metallurgy

1. Parts can be produced to net shape or near net shape, eliminating or reducing the need for subsequent machining.
2. Minimal waste of material; about 97 per cent of material powder is converted to product.
3. Parts can be made with desired level of porosity to produce porous metal parts.
4. Metals and non-metals can be mixed together in any proportion.
5. Complex shapes can be produced. Close dimensional tolerances of order of ± 0.02 mm are possible.
6. Rate of production in this process is very high.
7. It can also be used to produce products with special characteristics.

Disadvantages of Powder Metallurgy

1. Powder metallurgy is not suitable for all metals and alloys.
2. Cost of equipment and machines is high.
3. It is not economical for small scale production.
4. Metal powders are expensive and special care is not easy.
5. Sintering of low melting point metal powders is not easy.
6. Very complex shapes and intricate designs are difficult to obtain.

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