Department of Aerospace Engineering

19AST202 AIRCRAFT PRODUCTION TECHNOLOGY.

UNIT III POWDER METALLURGY AND UNCONVENTIONAL MACHINING

Powder metallurgy in Aerospace – Process – finishing methods advantages and applications

Powder metallurgy *is defined as the art of making objects by the heat treatment of compressed metallic powders.*

''Powder metallurgy'' includes the blending and mixing of powders, pressing or compacting powder into an appropriate shape, sintering the pressed-powder compact, and perhaps final sizing or finishing of the product to meet specified dimensional tolerances.

The process is applicable to a single metal powder, to mixtures of metals and non-metals. The operation of pressing may be carried out at ordinary or elevated temperatures depending upon the composition and properties desired in the product.

ADVANTAGES, DISADVANTAGES/LIMITATIONS OF POWDER METALLURGY

Advantages :

The advantages of powder metallurgy are :

1. Such parts which have special properties can be produced which otherwise cannot be obtained.

2. Machining operations are eliminated.

3. Scrap losses are reduced and often results in lower unit cost for a given part in comparison to any other production method.

4. Metals and alloys can be mixed together in any proportion which is difficult and sometimes not possible by melting.

5. Metals and non-metals can be mixed together in any proportion.

6. There is better control of composition and structure of the component by this process.

7. Articles of any desired porosity can be manufactured.

8. Super-hard cutting bits, which can never be manufactured by any other methods are made by powder metallurgy, e.g., sintered carbides, satellites.

9. This process is suitable for mass production because the stroke of the pressing or compacting consists of a press at a speed of 60 strokes/minute.

10. Antifriction alloy strips made by powder metallurgy can be made to adhere on a strong

alloy backing piece.

11. The process is very economical and the loss of material is lesser as compared to other processes.

12. Diamond impregnated tools for cutting porcelain, glass and tungsten carbides are made possible only by powder metallurgy.

Disadvantages/Limitations :

The process has the following disadvantages/limitations :

1. Owing to the fairly high compacting pressures required to press the powder, the wear on the dies is high.

2. Due to high rate of wear of dies, high costs for dies and presses the method is rendered uneconomical particularly for small runs.

3. Since the compacted parts must be ejected from the die without fracture, therefore, the shapes that may be made by this method are limited.

4. Equipment's required are very costly.

5. A completely dense product is not possible without heating the product after pressing operation.

6. The physical properties obtained by this process are lower than those obtained by other

processes.

7. In the low melting powders like tin, zinc and cadmium, sometimes certain thermal difficulties appear.

8. Pressed and sintered powder can approximately achieve the properties of the wrought

alloy but at the cost of increased production cost.

9. The intricate shapes cannot be made by compacting since metal powders cannot flow like fluid under compact load.

10. The products are of small size because for large size bigger equipments and tools would be necessary involving very heavy investment.

11. Many metal powders are explosive at room temperature.

12. A few metals cannot be compressed because they have a tendency to cold-weld to the walls of the die causing wear on the die

APPLICATIONS OF POWDER METALLURGY

Powder metallurgy has the following present day applications :

1. Porous and graphite containing metal bearings. 2. Electrical contacts consisting of a current and heat-conducting matrix in which are embedded wear resisting particles.

3. Tungsten wires. 4. Rotors of gear pump. 5. Diamond impregnated tools. 6. Magnetic materials.

7. Refractory metal composites. 8. Metal to glass seals. 9. Motor brushes. 10. Metallic filters.

11. Metallic coatings. 12. Babitted bearings for automobiles. 13. Cemented carbides. 14. Friction materials.

MANUFACTURE OF PARTS BY POWDER METALLURGY

The manufacture of parts by powder metallurgy involve the following steps :

1. Production of metal powders. 2. Blending powders.

3. Pressing or compacting of metal powders.

4. Sintering. 5. Finishing operations.

Production of Metal Powders

The methods of powder production are :

1. Atomising 2. Gaseous reduction

3. Electrolysis process 4. Carbonyl process

5. Stamp and ball mills 6. Granulation process

7. Mechanical alloying 8. Other methods.

1. Atomising process. In this process the molten metal is forced through an orifice into a stream of high-velocity air, steam or inert gas. This causes extremely rapid cooling and disintegration into a very fine powder.

The use of this process is usually limited to metals with low melting point.

2. Gaseous reduction. This process consists of grinding the metallic oxide to a finely divided state and then reducing it by hydrogen or carbonmonoxide.

It is employed for metals such as iron, tungsten and copper (whose melting points are near or above 1100°C).

3. Electrolysis process. In this process of producing powders the conditions of electrode position are controlled in such a way that a soft spongy deposit is formed ; which is then pulverised to form the powder. The particle size can be varied over a wide range by varying the electrolyte composition and various electrical parameters. The powders of copper, iron and other metals are made by this process.

4. Carbonyl process. This process is based upon the fact that a number of metals can react with carbon monoxide to form what are known as carbonyls. For example, the iron carbonyl is made from iron reduced from ferric oxide. Carbon monoxide at a pressure of 48–200 bar is then passed over heated iron. The resulting carbonyl is decomposed by heating to a temperature of 200°C to 300°C.

This process yields powders of high purity but entails a heavy cost.

5. Stamp and ball mills. These are mechanical methods which produce a relatively coarse powder. The ball mill is employed for brittle materials while stamp mill for more ductile materials.

The cost is usually high, and the powders produced by these methods are usually treated to remove the cold work-hardening received in the process.

6. Granulation process. This process consists in the formation of an oxide film on individual particles when a bath of metal is stirred in contact with air.

This process produces a relatively coarse powder with a high percentage of oxide.

7. Mechanical alloying. In this method, powders of two or more pure metals are mixed in

a ball mill. Under the impact of the hard balls, the powders repeatedly fracture and weld together by diffusion, forming alloy powders.

8. Other methods. Other, less commonly used methods include :

(i) Precipitation from a chemical solution.

(ii) Production of fine metals by machining.

(iii) Vapour condensation.

New developments include techniques based on high temperature extractive metallurgical

processes. Metal powders are being produced using high temperature processing

techniques based on :

—The reaction of volatile halides with liquid metals ;

—The controlled reduction and reduction/carburization of solid oxides.

Recent developments include the production of nanopowders of various metals such as copper, aluminium, iron and titanium. When the metals are subjected to large plastic deformation at stress levels of 5500 MN/m2, their particle size is reduced, and the material becomes pore free and thus possesses enhanced properties.

Blending of Metal Powders

The process of blending (mixing) powders is carried out for the following *purposes:* (*i*) To obtain *uniformity* (since the powders made by various processes may have different sizes and shapes).

(ii) To impart special physical and mechanical properties and characteristics to the powder metallurgy product.

(iii) Addition of lubricants (e.g., stearic acid, zinc stearate in proportion of 0.25 to 0.5% by weight) to the powders improve the flow characteristics of the powders. Such blends result in reduced friction between the metal particles, improved flow of powder metals into the dies, and longer die life.

In order to avoid contamination and deterioration, powder mixing must be carried out

under controlled conditions. The metal powders like aluminium, magnesium, titanium, zirconium, and thorium powders are explosive owing to their high surface area to volume ratio consequently, a great case must be exercised during their blending, storage and handling.

Pressing or Compaction of Metal Powders

The principal object of pressing or compacting is to effect cold-pressure welds between the

particles so that some cohesion is conferred, this is usually measured by the strength of the green

compact and is termed the green strength.

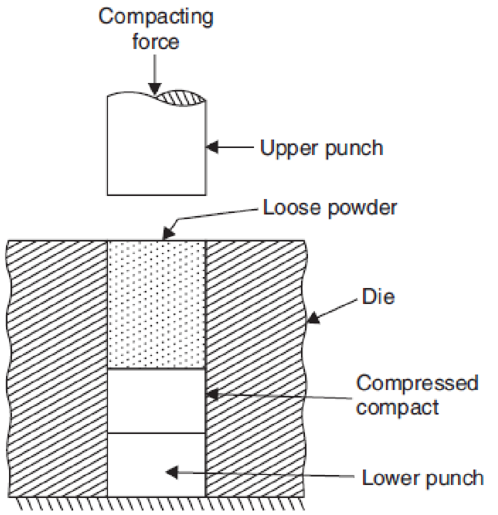
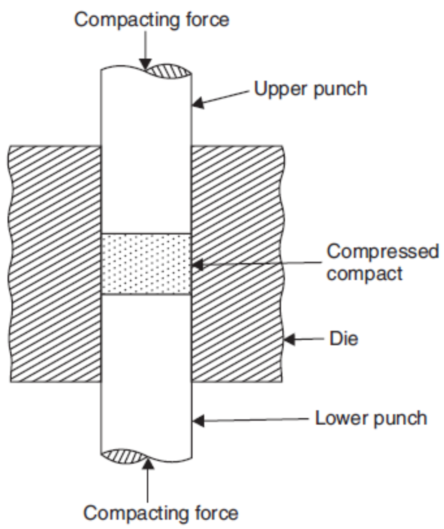
Compacting exercises the following effects :

(i) Reduces voids between powder particles and increases density of the compact.

(ii) Produces adhesion and cold welding of the powder and sufficient green strength.

(iii) Plastically deforms the powder to allow recrystallisation during subsequent heating.

(iv) Plastically deforms the powder to increase the contact areas between the powder particles, increasing green strength and facilitating subsequent sintering. Pressing or compacting is carried out by pouring a measured amount of the metal powder into the die cavity and then compacting the metal powder into coherent mass by means of one or more plungers (Fig.). Compressing from both top and bottom (Fig.) of the compact is better than compressing from the top only (Fig.), as pressure distribution and porosity distribution are more uniform.

	
Pressing or compacting one or more plungers.	Pressing or compacting from top and bottom.

— To improve uniformity of pressure and porosity through the piece the use of lubricants graphite, strearatex and zinc, aluminium and lithium strearate is made. Bond strength between particles is affected by the area of contact and by the cleanliness of particles (oxide layers being common sources of difficulty).

— The *compacting pressure required depends on the characteristics and shape of the particles, the methods* of *blending, and the lubrication.* The pressure required for pressing metal powders range from 70 MN/m2 for aluminium to 800 MN/m2 for high-density iron parts.

_ In compacting powders in steel dies at room temperatures pressures from 7.5 to 37.5 (sometimes 150) kN/cm2 are employed. Mechanical presses are employed for 500 kN and hydraulic presses for higher pressures. The moulding of small parts at great speeds and at relatively low pressures can be best accomplished in the mechanical press. However, large parts and parts to be moulded at higher pressures are best moulded in hydraulic presses.

— Extremely hard powders are slower and more difficult to press ; some organic binder is usually required to hold the hard particles together after pressing until the heat of sintering creates atomic bonds and promotes welding.

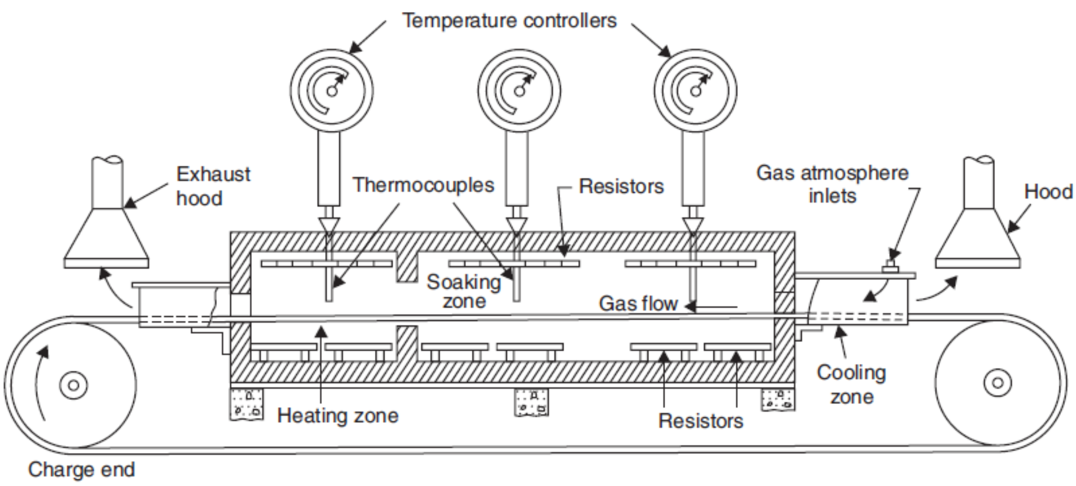
— In hot pressing if the powder is heated to proper temperature the pressure for complete densification is only 150 to 300 bar. Hot pressing requires a die material having appreciable high strength. Since even sturdy dies (made of graphite) usually sustain only one operation, therefore, *hot pressing is limited to the manufacture of articles of costly metals*.

Sintering

Sintering *means the heating of pressed compact to below the melting temperature of any constituent of the compact, or atleast below the melting temperature of all principal constituents of the compact.* Such heating facilitates *bonding action* between the individual powder particles and *increases the strength of the compact.* Heating is carried out *in a controlled, inert or reducing atmosphere, or in vacuum to prevent oxidation.*

— Prior to sintering, the compact is brittle, and its strength, known *as green strength* is low. The nature and strength of the bond between the particles, and hence of sintered

product, depend on the *mechanism of diffusion plastic flow, evaporation of volatile materials in the compact, recrystallization, grain growth, and pure shrinkage.*
During the sintering process bonding of the individual powder particles takes places in any of the following three ways :
(*i*) Melting of a minor constituent ;
(*ii*) Diffusion ;
(*iii*) Mechanical bonding.
The important factors which control sintering are : (*a*) *temperature*, (*b*) *time, and* (*c*) *furnace atmosphere.* The sintering temperatures used vary with the compressive loads used, the type of powders, and strength required of the finished part.
— Aluminium and aluminium alloys can be sintered at temperatures from 350° to 500°C for periods up to 24 hours.
— Copper and copper alloys can be sintered at temperatures ranging from 700°C to temperatures that may melt one of the constituent metals.
— Compacts of iron powders are usually sintered at temperatures from 1000°C to 1200°C for approximately half an hour.
_ During sintering, ordinarily, the density of the compact is increased and shrinkage results. Shrinkage fills the holes within the compact, increases the areas of contact and reduces the size of the holes in the compact. Shrinkage can be controlled by careful selection of the metal powder and determination of the correct pressure for cold forming.
Sintering may be carried out in batches or continuously in batch type and continuous furnaces respectively.
— Batch type furnaces prove useful for laboratory or experimental work while continuous furnaces are more suitable for production work.
— A continuous furnace usually comprises three zones. The first zone warms the pressed parts and the protective atmosphere used in the furnace purges the work of any air or oxygen that may be carried into the furnace by work or trays. In the second zone the work is heated to the proper sintering temperature. The third zone cools the work to a temperature that allows handling. **Fig.** . shows a continuous-conveyor-type sintering furnace



Sintering furnace.