Unit 8 (Class15) Powder Metallurgy

Today's Portion

We shall learn about
Another Manufacturing process called as
Powder Metallurgy

The topic deals with the production of net shaped components having very high strength, Wear resistance, fatigue resistance combined with other properties.
As the name suggests it involves knowledge of metallurgy, material science and design.
We shall learn what are the raw materials required.
How powders are produced.
How they are blended.
How they are compacted.
How they are sintered. Equipments used.
How they are processed further.
What are the applications?

Advantages and Limitations of Powder Metallurgy.

- Powder Metallurgy (PM) is a process for fabricating components by compacting finely powdered metallic or non metallic or both materials.
- It is solid state fabrication technique.
- Two or more metallic and/or non metallic powders are thoroughly blended together in a machine and then compacted at very high pressure using a die.
- The compacted powder will be still in the green state (to be handled carefully).
- The green compact is taken out of the die and sintered at very high temperature to get a hardened mass having the desired configuration with enhanced strength and other mechanical properties.

Processing Stages of Powder Metallurgy

*First the primary material is powdered and divided into many small individual particles.

*Two or more metal and or non metals are mixed or blended together to form a homogeneous mixture.

*The blended mix is introduced into a mold cavity or a die and pressed to produce a weak cohesive mass called as green compact.

*The green compact is then subjected to very high temperature and pressure for a known time to get a hardened mass.

Steps involved in PM technique

1. Preparation of powders: very fine powders are obtained using various techniques.

2. Blending of powders: The fine powders are mixed along with a lubricant. The lubricant helps in imparting good fluidity to the powders.

3. Compacting: The blended powder is compacted in a mold or die.

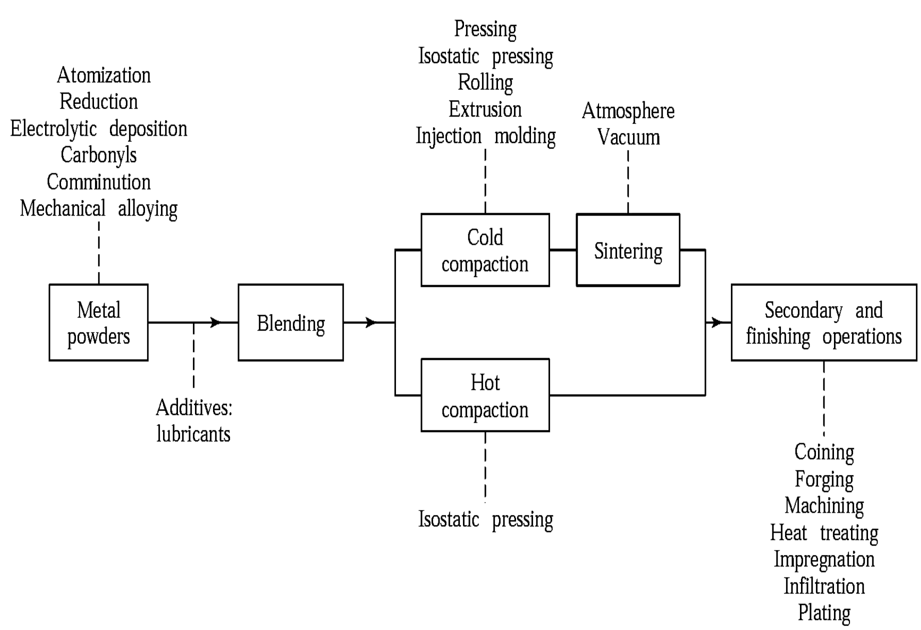
4. Sintering: The compacted mass is sintered at a high temperature in a furnace in a controlled atmosphere.

5. Sizing: The sintered component is passed in a mold or dies to trim the component and achieve high dimensional accuracy.

6. Machining: If required final machining is done on some specific locations including drilling very small holes.

7. Treatment: Parts are subjected to deburring and tumbling to remove any small projections and other treatments like oil impregnation tec., are given.

8.Inspection: Finally parts are inspected to check the quality .



Advantages of Powder Metallurgy

• Virtually unlimited choice of alloys and non metallicswith associated properties.
* A variety of metal or non metal powders can be used.
* Refractory materials are popularly processed by PM.
• Can be very economical for mass production (100,000parts).
• Long term reliability through close control of dimensions and physical properties.
• Very good material utilization - loss of material very less.
• Minimization or elimination of Machining.
• Very good surface finish can be easily obtained.

Limitation of Powder Metallurgy

* Initial Investment cost high
*Limited part size and complexity
*High cost of powder material.
*High cost of tooling.
*Less stronger than wrought ones.
* Fracture toughness may be low.
*Less well known process.
* Health hazard to the operator due to very fine powder being processed.

Applications of Powder Metallurgy

- •Only method for shaping super alloys and tungsten carbides.•Automobile parts- A commercial US car contains approximately 15Kg of PM parts.•Aerospace –A commercial aircraft engine is composed of 700-2000Kg PM parts.Gears, Cams, Sprockets, Cutting tools, Piston rings, connecting rods and many house hold goods are produced by PM technique

The following steps are used in the powder metallurgy techniques:

1. Production of Metal Powder
2. Blending of metal powders + additives.
3. Compaction of the blend using cold compaction & hot compaction methods. (Isostatic compaction, rolling, extrusion, injection moulding etc.,).
* A die is used for the above process to get net shaped green component.
4) Sintering of the green component at very high temperature to impart necessary hardness and strength to the component.
5) The above component is subjected to secondary & finishing operations such as forging, machining, coining, plating etc.,

Step.1.Production of Metal powders

*Metal powders are produced by using a variety of techniques, the size of the particles range from 0.1 to 1000µm. *Bulk metals and alloys, ores, and other compounds are used.*The shape, porosity, purity, size and distribution of the particles depends on the type of process used.

The methods normally used for the production of metal powder are

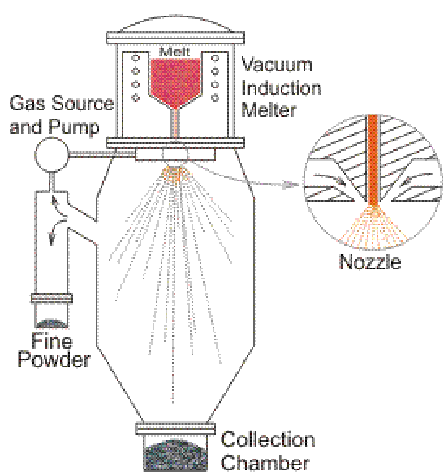
a. Atomization.
b. Reduction
c. Electrolytic deposition
d. Pulverization
e. Mechanical alloying
f. Others

Atomization.

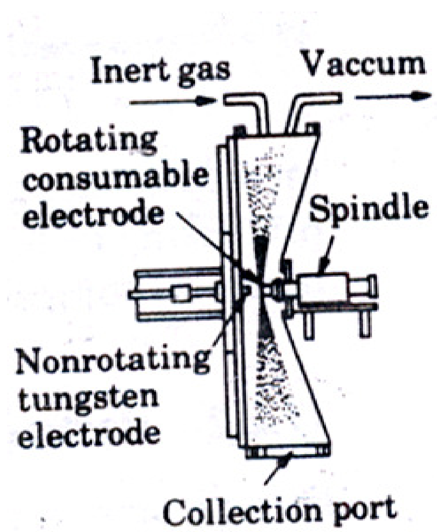
Here the liquid metal stream is produced through a small orifice and the stream is broken by a jet of inert gas/water/air.

Finely divided particles are obtained. The size of the particle depends on the temperature of the metal, flow rate, nozzle size & jet characteristics.

A continuous uniform production of metal powders can be obtained .



Atomization Process



Rotating Electrode Method

As the molten metal is entering the nozzle inert gas is forced through the annular space of the nozzle. This will create a very fine spray of metal and fine particles are collected in the chamber.

Rotating Electrode Method

In this method a consumable electrode(Metal rod) is rotated rapidly in a helium gas filled chamber.The centrifugal force breaks up the molten tip of the electrode, producing particles. Opposite to the spindle tip a non rotating electrode establishes an arc which heats the metal electrode which is rotating. Tiny droplets of metal are formed.

Electrolytic deposition

Here Electrolytic method using an aqueous solution is used for fine deposition of powders on the cathode.
The powder thus produced will be in its purest form.

Pulverization

In this method metals (brittle & less brittle) are crushed in a ball mill to produce small particles.

In a ball mill, using rotating hollow cylinders, partly filled with steel or white cast iron balls, the metals are crushed.
Repeated rotation of hollow cylinder results in crushing of the metal.
Brittle metals will produce particles of angular shapes.
Ductile metal will produce flake particles. (Hence, not suitable for powder metallurgy application).

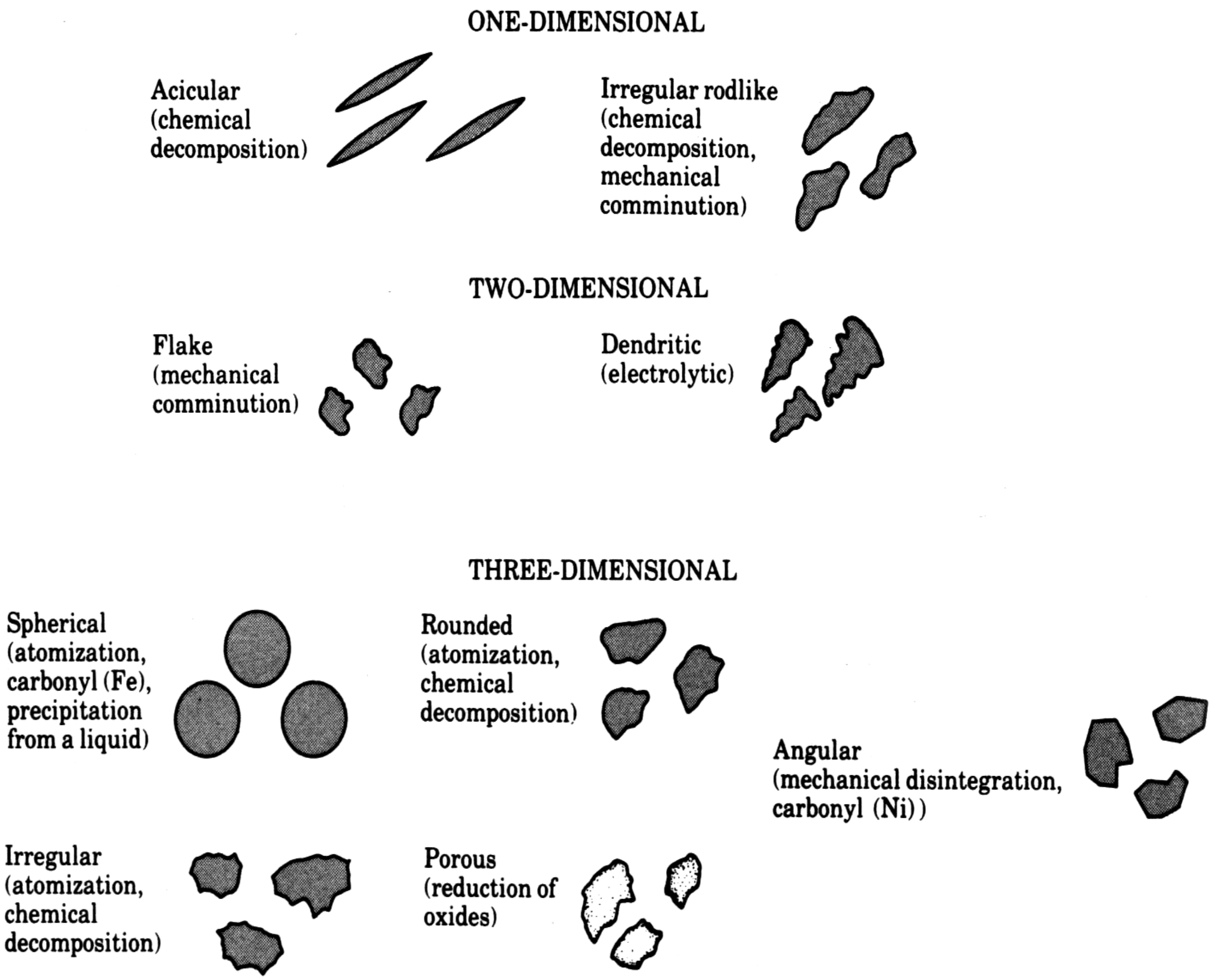
Mechanical Alloy

In this method, powders of two or more metals are mixed in a ball mill.
Due to impact of hard balls, the powders undergo fracture and weld together by diffusion, forming alloy powders.

Other methods

Some of the methods which are used in addition to the above are:

- Precipitation from a chemical solution.
- Production of fine metal chips by Machining & Vapor deposition.



Size of powders 0.1 um – 1 mm   Sieve size quoted as mesh number
*Particle D = 15/mesh number(mm)   325 mesh ◊45 μm

Step 2. Blending Metal powders

Here powders of two or more metals having different size & shapes are mixed to get a uniform mixture.
The ideal mixture consists of Particles having uniform distribution.
Powders of different metals are mixed to improve physical & mechanical properties as required.

To improve the flow characteristics, lubricants are mixed with the metal powder.
This will insure proper filling of the dies and improves the die life.
About 0.25 to 5% by weight Zinc stearate or stearic acid are used as lubricants.
Mixing of powder must be carried out under controlled conditions to prevent contamination.

3.Compaction of Powder

*In this step, the blended powders are pressed into shapes in dies using presses activated by hydraulic & mechanical means. The pressure is around 70-800Mpa.
*By pressing, the required shape with the desired density, with good particle to particle contact can be obtained.The pressed powder is referred to as green compact.
Pressing is generally done at room temperature, but can also be carried out at elevated temperature.*The density of the green compact depends on the pressure applied.*As the compacting pressure is increased, the density approaches that of the theoretical density of the metal in the bulk form.*If the size of the particles are the same then there will always be some open spaces between the particles.

This space is referred to as porosity.*In general, the porosity will be around 24% by volume.*Introducing smaller particles will fill the spaces between the larger particles and thus result in a higher density of the compact.*Higher the density, higher will be the strength and elastic modulus of the part.

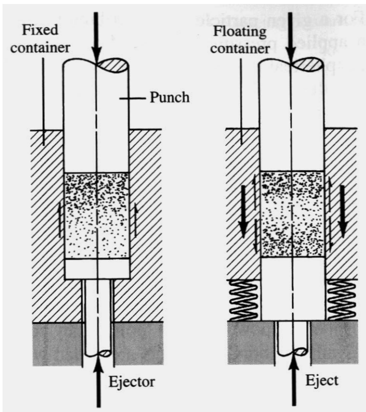
Methods of compaction

Powders are compacted by any one of the methods:

*Using a punch and a die.
*By Rolling.
*By Extrusion.
*By Injection moulding.
*By Isostatic pressing.

Using punch and a Die

*Here a punch and a die assembly is used. *The metal powder mixture is filled in the die and the punch is forced on it. The powder gets compacted. *The range of pressure used for compaction is shown in the table.



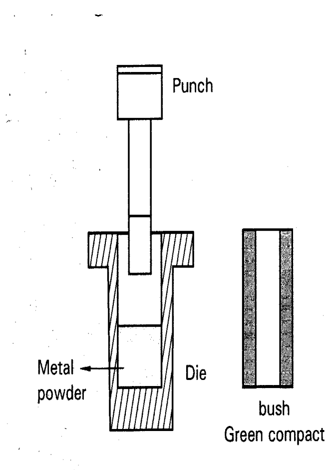


Table 8.1 Compaction Pressure	
Material	Pressure MPa
Al	70 - 275
Brass	400 - 700
Bronze	200 - 275
Iron	350 - 800
Ti	70 - 140
W	10 - 140
Al_2O_3	110 - 140
Carbon	140 - 165
Cemented Carbides	140 - 400

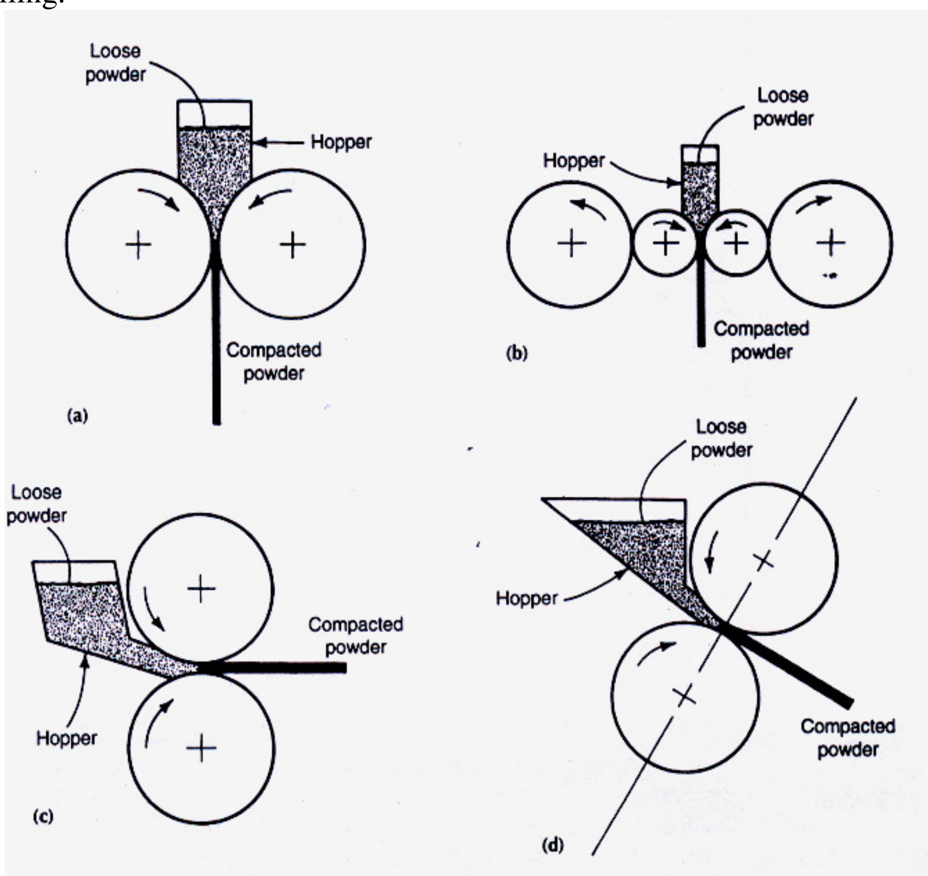
Pressing of Powder

Part B

Unit8 (Class16) Powder Metallurgy

Powder Production Reduction,Electrolytic deposition, Pulverization, Mechanical Alloy and othersBlending of powdersCompaction of Powders Punch and Die,Rolling, Extrusion, Injection Moulding, Isostatic Pressing SinteringTypical Sintering set up

Powder Rolling
*In powder rolling (powder compaction) the powder is fed into the roll gap in a two high rolling mill and is compacted into a continuous strip at speeds up to 0.5m/s.*The process can be carried out at room temperature or at elevated temperatures.*Sheet metal for electrical and electronic components, coins can be made by powder rolling.



. 1 Typical roll positions. (a) and (b) Horizontal positioning. (c) Vertical positioning. (d) Inclined angle positioning

Powder Extrusion

*Powders can be compacted by extrusion.*The metal powder is encased in a container and extruded.*After sintering, preformed PM parts may be rolled or forged in a closed die to their shape.

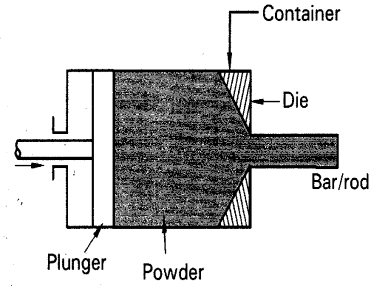
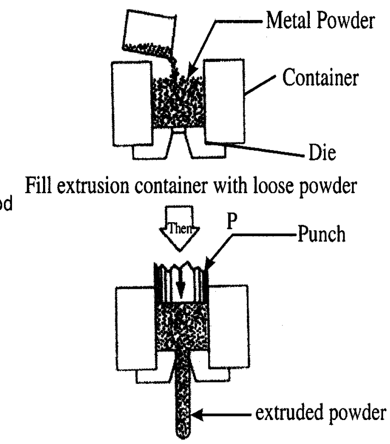


Fig. 8.11 Powder Extrusion

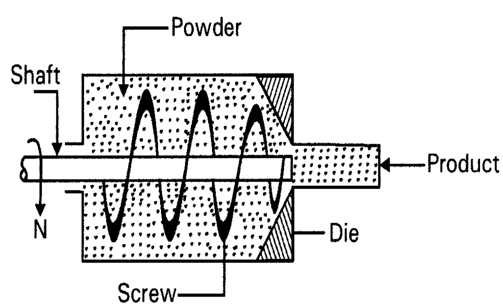


Hot extrusion methods for metal powders

Powder Injection Moulding

*It is also called metal injection moulding.*Very fine metal powders (<10μm) are blended with a polymer or a wax based binder.*The blended mixture undergoes compaction due to pressure.*The green compacts are heated in a oven at low temperature to burn off plastic and then sintered in a furnace.

Pressing can be carried out either at room temperature or at elevated temperature. *The powder must flow easily into the die cavity.*The density of the green compact, depends on pressure applied during compaction.*By using particles of different shape, very close packing of the metal powder can be achieved*Higher density results in higher strength and higher elastic modulus of the components.



The normal compaction pressure ranges from 70Mpa for aluminium to 800Mpa for iron parts.*Crank or eccentric type mechanical presses are used for small tonnage.*Toggle or knuckle joint presses are used for higher capacities.
*Hydraulic process (450MN) are employed for large components.
Compaction can also be carried out by a number of other processes such as

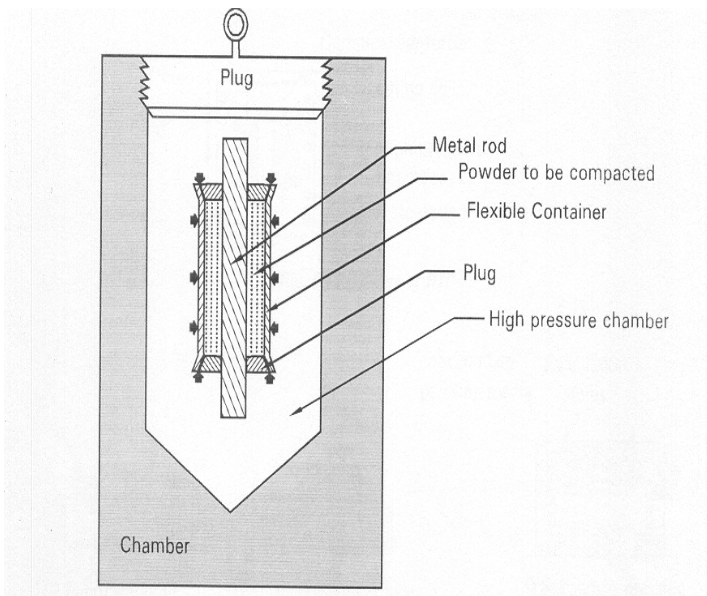
isostatic pressing, rolling and forging.*Since the density of the compacted powders can vary significantly, green compacts are subjected to hydrostatic pressures in order to achieve more uniform density.

Isostatic pressing:

*This type of operation is used for compaction of powders. *The process is similar to pressing using cupped hands for making snow balls.

Cold Isostatic Pressing

*In cold isostatic pressing (CIP) the metal powder is placed in a flexible mould made of rubber or Urethane or PVC.*The assembly is then pressurized hydrostatically in a chamber usually using water. *Pressures of 400 to 1000MPa are used.



Cold Isostatic Pressing

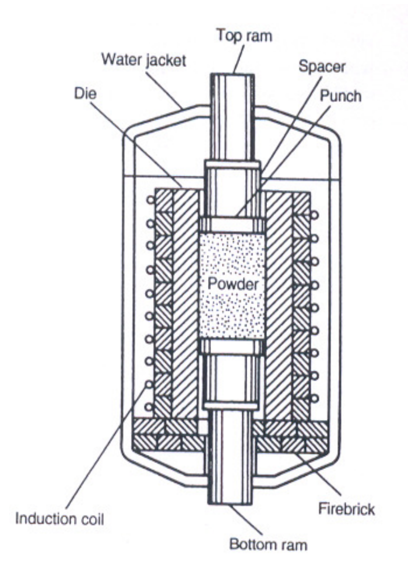
The powder is enclosed in flexible container around a solid core rod. Pressure is applied isostatically to the assembly inside a high pressure chamber. The powder gets compacted and the green compact is taken out and sintered.

Hot Isostatic Pressing

In Hot Isostatic Pressing (HIP) a metal powder is stressed using inert gas in a metal container. *Pressure of 100MPa at 1000oC is used.*Here a container made of very high melting point metal is used.*An inert gas is used as the pressuring media.The main advantage of HIP is its ability to produce compacts with essentially 100% density, good

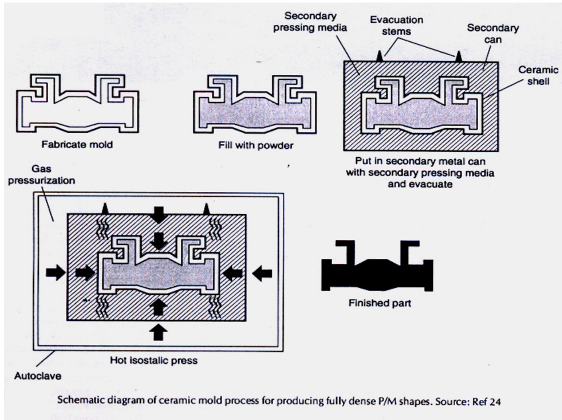
metallurgical bonding among the particles with good mechanical properties*HIP process is relatively expensive
and is used for making super alloy components for aerospace industry.
*It is regularly used for the densification of WC cutting tools and PM tool steels.

HIP is also used to close the internal porosity and improve properties in superalloy and Ti alloy castings for the aerospace industry.The main advantage of isostatic pressing is the absence of wall friction as pressure is being applied from all directions.It produces compacts of practically uniform grain structure and density irrespective of shape.

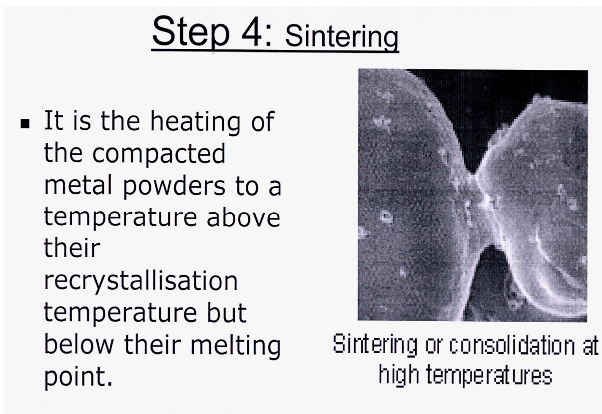


Hot Isostatic Pressing

Figure shows the details of producing PM component.Here a mold is used into which metal powder is filled.This is then surrounded by a secondary pressing
media.Then vacuum is applied.The entire assembly is kept in an autoclave Chamber and subjected to HIP.Necessary pressure is applied through the chamber
and temperature is maintained at a known value. As a result the compacted metal powder gets sintered Finally the component is taken out of the system to get the finished part.



Schematic diagram of ceramic mold process for producing fully dense P/M shapes. Source: Ref 24



Sintering

Sintering is a process wherein the compressed metal powder is heated in a controlled atmosphere using a furnace. The temperature of the furnace will be slightly below melting point of the metal powder but above the RCT.
After sintering, the strength of the metal compact will be very high.
Sintering mechanisms are highly complex in nature & depends on the composition of the metal powder and the processing parameters.

Normally at high temperatures the particles begins to form a strong solid state bonding by diffusion.This results in high strength, high density, high ductility and other properties.During sintering the component undergoes shrinkage as in castings.
This needs to be taken care of.

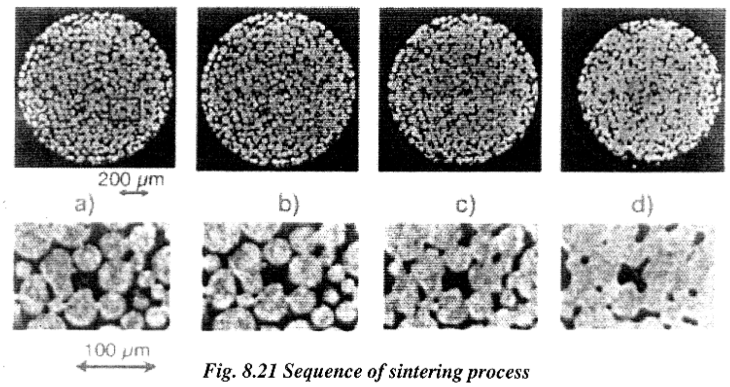


Fig. 8.21 Sequence of sintering process

The sintered component is taken and necessary grinding/finishing of the component is carried out, such that the final dimensional accuracy is achieved.

For this, a variety of machining operations will be carried out.