Compaction

(P-1)

Consolidation of Metal and Ceramic powders

(I) purpose of compacting :→ There is three fold of purpose of compacting.

(a) compacting of powder is done, in order to get the desired shape. The shape should be simple, in order to avoid damaging of compacts during handling before sintering. Very completed complicated shape may lead to warpage or cracking due to much density variation in the green compact during sintering. It can not rectify.

But today very complicated shapes are obtained by latest technique of compacting is known as Metal Injection Moulding (MIM) and Ceramic Injection Moulding (CIM)

(b) In order to get desired size and dimensional accuracy, compacting of the powders are necessary. In sintering there is dimensional changes, thus the tool compacting tools must be given some allowances, so that it can accommodate these changes in final products. usually there is shrinkage, leading to densification and strengthening on sintering.

2) Compacting is also done inorder to give the desired level and type of porosity within the compact. Type of porosity mean after sintering, all the pores are interconnected (for examples: in self lubricating bush-bearings, metallic filters, diffusers, distributors etc) or most of the pores are isolated (for example:- some structural parts or machine components required for a min^m or nil porosity to obtain max^m strength & density in the P/M products having very fine grain size.

② Die Compacting of powders: Die compacting of powders is very simple and most widely used method of compacting.

- Empty annular die cavity formed by putting a core rod at the centre of the die cavity is filled with the powder after closing the bottom of the cavity with the lower punch
- Both the punches are simultaneously pushed towards each other (for double side pressing), until the predetermined load is reached.

The top punch is then withdrawn, while the green compact is ejected out of the die by pushing the bottom punch upward and removed to facilitate another similar operation.

- Green compacts are carefully lifted by the operator from the die table and arranged in trays for transporting to the sintering furnace.

(3) Mechanism of compacting :→
or
Stages of compacting :→

There are three stages of compacting as shown in Fig (A):

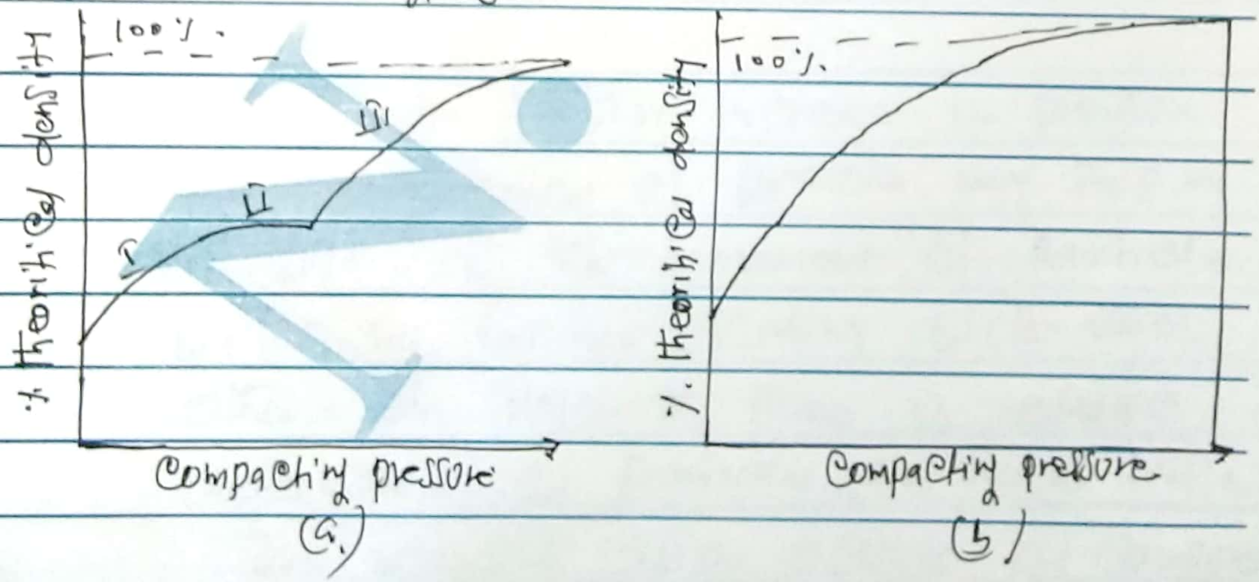


Fig (A) (a) Theoritical and (b) the actual curve of densification of metal powders under pressure (compressibility curve)

Stage I : [When pressure is applied on the loosely packed powder, which is present in die by pushing the top punch slowly inwards, then there is a rearrangement or reorientation of particles in the initial stage (Stage-I) of the application of pressure. In Stage-I, there is little densification due to improvement in the packing of particles by sliding with each other.]
In case of fine powders, there are the formation of arches and bridges within the powder mass, thus creating voids. At the initial stage (Stage-I), these arches and bridges collapse giving rise to more densification.

Stage-II: On further increase in pressure the rearrangement of particle may stop by blockage in the movement of particles with no further sliding with each other. In Stage-II, there is elastic deformation of particles and hence little more densification occurs as compared to Stage-I.

Stage-III: → [In third stage of compaction, major densification & strengthening take place.

[In this 3rd stage of compaction, the particles undergo extensive plastic deformation, which results into reduction in total internal porosity, some fracturing of the particles also occurs due to strain hardening.]

× — Thus fine particles are generated by strain hardening and fracturing of particles, which contribute to the densification by filling the interstitial spaces in the pressed products.

— [But in actual practice, three stages of metal powder compaction or compressibility curve of metal powders do not appear.

— They overlap each other and we get the actual curve as shown in Fig (5).

— The overlapping is due to the fact that during the process of rearrangement of particles, some particles may get locked with each other and they undergo elastic deformation as well as some plastic deformation at some places simultaneously. We can not distinguish these stages separately.

With further increase in pressure, extensive plastic deformation take place, which leads to high densification.

- Thus, in 3rd stage of compaction, densification ~~due~~ in actual practice is due to plastic deformation of metal powder particles.
- Therefore, typical compressibility curve is obtained as shown in fig (6).
- The green density increases with increasing the applied pressure and the curve gradually becomes flattens due to work hardening of the particles, ultimately giving no further densification.

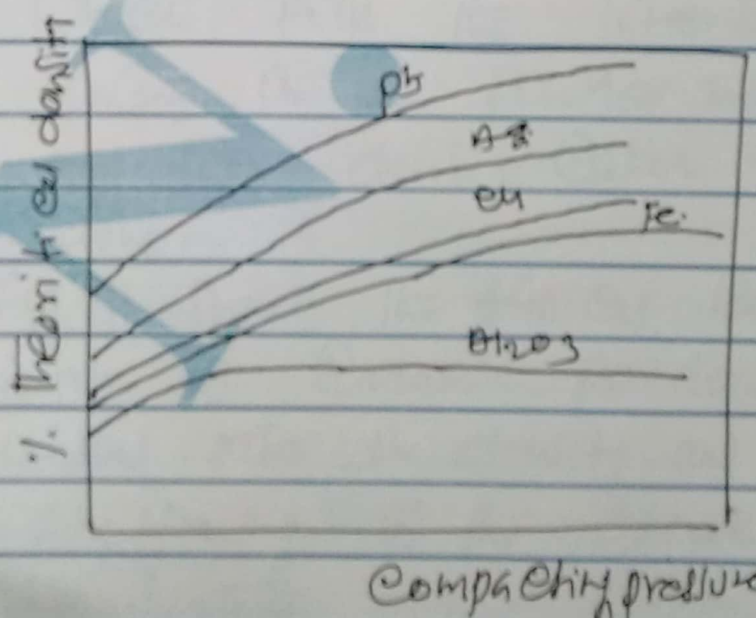


Fig (6): Compressibility curve of different metals & ceramic

Different metals have different compressibility curve, because of different work hardening characteristics as shown in Fig (B).

- In case of ceramic powder, compressibility curve is different as compare to metal, because, in ceramic particles, there is no plastic deformation.
- The curve (Fig B) shows a little rise in density on applying load at the initial period of compacting, due to rearrangement of particles and little elastic deformation, leading to fracturing of the corners and edges of particles.
- Thus generating fine particles which fills the interstitial spaces in the powder mass and little densification has been done.
- Fig (B) shows, the typical compressibility curve of ceramic powders showing initial rise in density and then flattening of the curve indicating no further densification

From this discussion, It was observed that two basic processes occur during the uniaxial compacting in a die:

- Bulk movement of particles
- Deformation and fractoring of particles

→ Sufficient bulk movement, rearrangement and reorientation of particles give efficient packing and by initial densification.

- In case of very fine powder particles, they formed arches and bridges within the powder mass, creating large voids, which collapse at the initial stage of compacting, thus increase the density.
- By further increasing the load leading to the major densification by excessive plastic deformation of the particles of metal. So, here effect of die wall friction comes.
- If the rate of bulk movement of the powder mass is high, means particles do not get much time to slide or reorient themselves giving lesser densification. On further increasing the load, there is little elastic deformation & there is major plastic deformation, leading to major densification.

The deformation of individual metal particles give significant strain hardening and ultimately fracturing. The fractured fine particles occupy the interstitial spaces in the powder mass, thus it also to help in increase in densification.

The factors increasing the green density of metal powders:→

- By increasing the compacting pressure
- By decreasing the rate of pressure application
- By increasing the plasticity or ductility of the powder particles.
- By increasing the apparent density of the powder.

We can find out the porosity in the green compact as follows:-

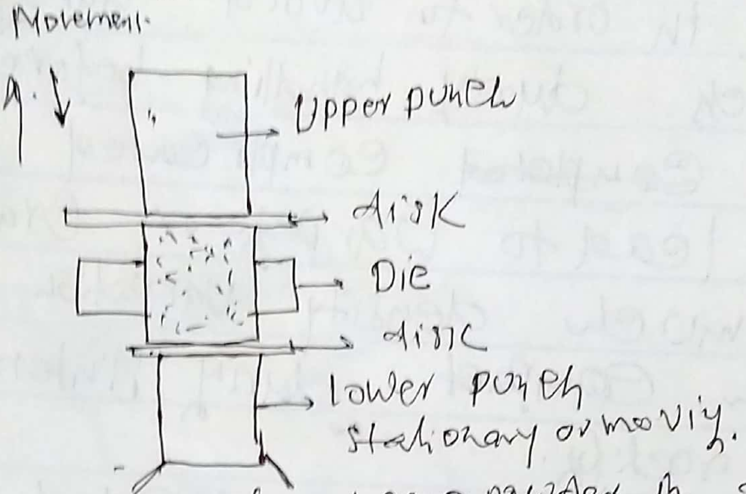
$$\% \text{ porosity} = (1 - \gamma_{relative}) \times 100$$

Where, $\gamma_{relative}$ = green density / Theoritical density.

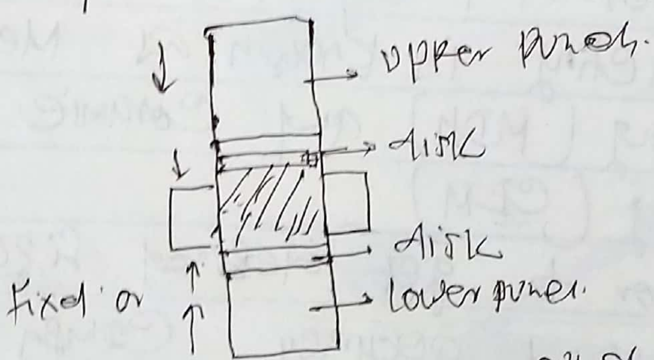
— Now consider the second important term of "wall pressure radially exerted on the die wall during consider mechanism of compacting:→

process of Compaction.

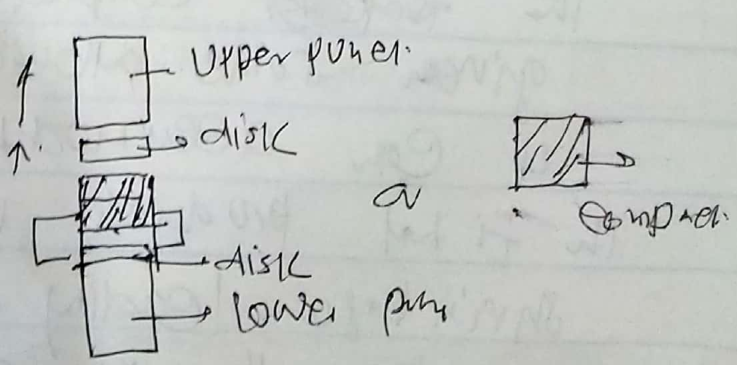
(i) Step (I) Filling of powders into Die



(ii) Step - II : compaction of powder in die by movement of punches.



(iii) Step - (III) : Movement of upper punch in reverse direction & compacted mass is push upward by raising the lower punch upward direction.



Die Materials:

- punches and dies are made of tool steel

- Tool steel is generally high carbon steel which is cheaper, but not as hard and is used for soft powders like, Al, Cu, & Pb (Non ferrous parts)

- Cementite carbides used for high wear & abrasive resistance powders like, steel, alloy steel powders etc. (Ferrous parts)

Equipment for Die Compacting :→

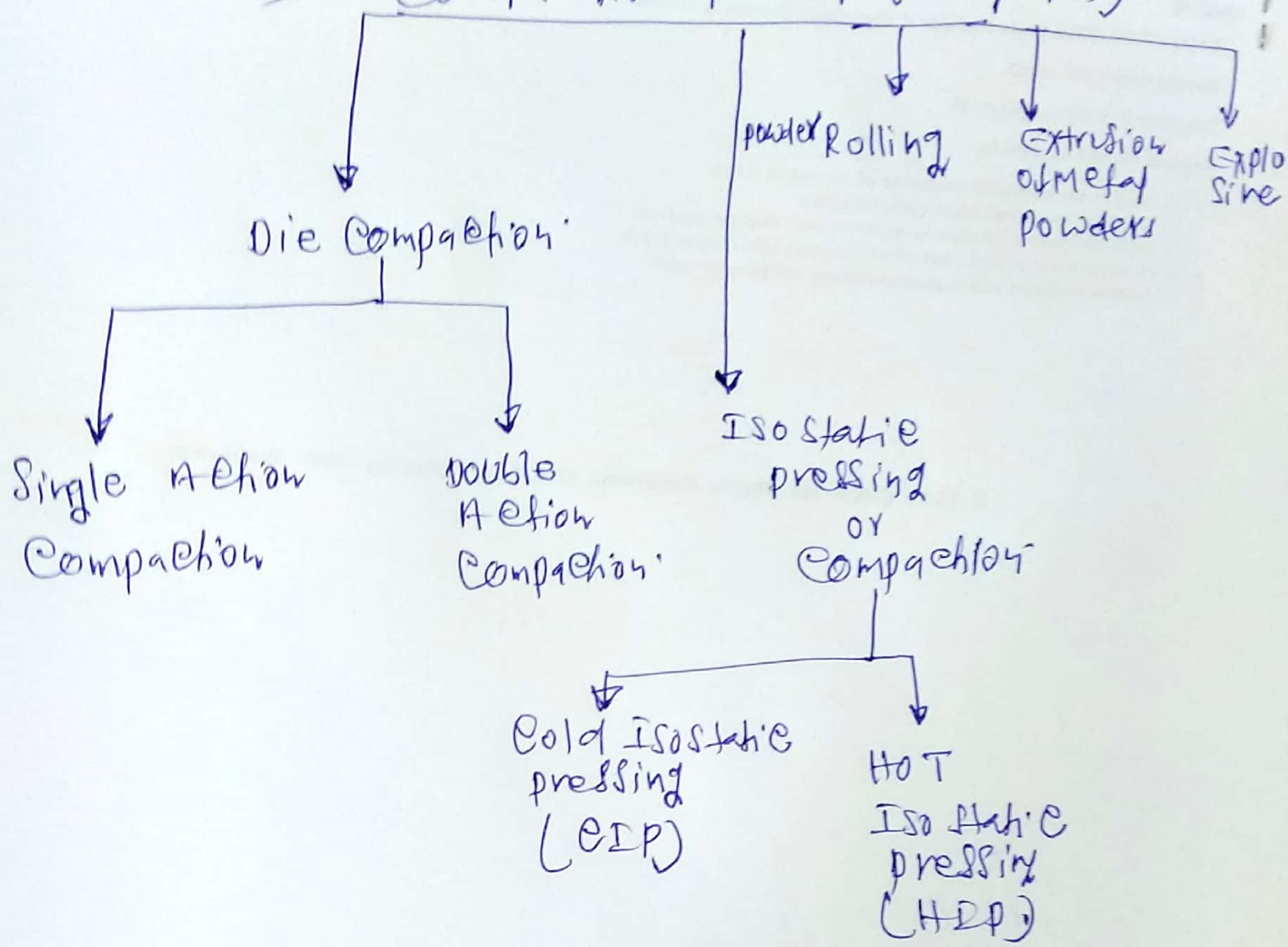
Compacting tools are : Die, punches and core-rods. For having a hole at the centre a cylinderical core rod is used.

– In order to minimize wear & tear of the die wall due to rubbing b/w die & punches and b/w die & the powder mass, the hardness of the die is always kept little higher than that of the punch because of the die is more expensive as compared to punches and core rods, which can not be changed frequently.

× – Usually ~~these~~ these tools are made of heat treated (hardened) high strength low alloy (HSLA) steel i.e. AISI 4340.

☐ Tool design in Die Compacting. Refer book page no: 93, 94 and 95, 96 ~~98~~, 97.

(I) Compaction process (Category A)



Category A: Associated with pressure.

(II) Another category of powder compaction is pressureless Technique or process: —
Slip casting of Metal powders.

Note: Students are requested to go through the above process through NPTEL video lecture or available free PDF book on PM.

Read as: — Introduction/Definition of process
— Advantages & limitations of the process
— Applications of the process