EXPERIMENT NO 6

Conventional die compaction of powders

Objective:

To study the basic powder compaction technique to achieve compact properties with minimal wall friction.

Basic Theory:

- Powder metallurgical processing is widely used for producing near-net shape engineering components.
- Most applications for powder metallurgy dictate that high densities can be attained in the final product.
- Powders that exhibit good sintering densification can be shaped using low pressures, often with the aid of an organic lubricant.
- Compaction relies on an external source for deforming the powders into a high-density component that approaches the final geometry.
- The compaction of metal powders has the following major functions:
  (a) to consolidate the powder into desired shape
  (b) to impart, to as high a degree as possible, the desired final dimensions with due consideration to any dimensional changes resulting from sintering.
  (c) to impart the desired level and type of porosity.
  (d) to impart adequate strength for subsequent handling.
- Several approaches exist for achieving these goals. In general, the techniques can be categorized as
  (a) continuous vs discontinuous process,
  (b) pressures – high vs low,
  (c) compaction velocity – high vs low
  (d) temperature -room to elevated temperature;
  (e) uniaxial vs hydrostatic pressures.
- Die compaction represents the most widely used method and is considered as the conventional technique.
- This involves rigid dies and special mechanical or hydraulic presses.
- Densities of up to 90 % of full density can be achieved following the compaction cycle, the duration of which may be of the order of just a few seconds for very small parts.
- The friction between the powder and die wall and between individual powder particles hinders the transmission of pressure.
- A high uniformity in green parts can be achieved depending on:
  – the kind of compacting technique
  – the type of tools

– the materials to be pressed and the lubricant.

The compacting techniques used may be characterized by references to the movement of the individual tool elements – upper punch, lower punch and die relative to one another.

Pressing within fixed dies can be divided into:

– Single action pressing
– Double action pressing

- **Single action pressing:** the lower punch and the die are both stationary. The pressing operation is carried out solely by the upper punch as it moves into the fixed die. The die wall friction prevents uniform pressure distribution. The compact has a higher density on top than on the bottom.
- **Double action pressing:** only the die is stationary in the press. Upper and lower punches advance simultaneously from above and below into the die. The consequence is high density at the top and undersides of the compact.

Compaction pressure can be generated in a simple uni-axial press using mechanical, pneumatic or hydraulic forces. As pressure increases, the particles are packed more tightly thus increasing the green density.

As shown in Figure 1, the initial rate of densification with the application of pressure is high. With continued deformation the slope of the density versus pressure curve decline reflecting particle work hardening.

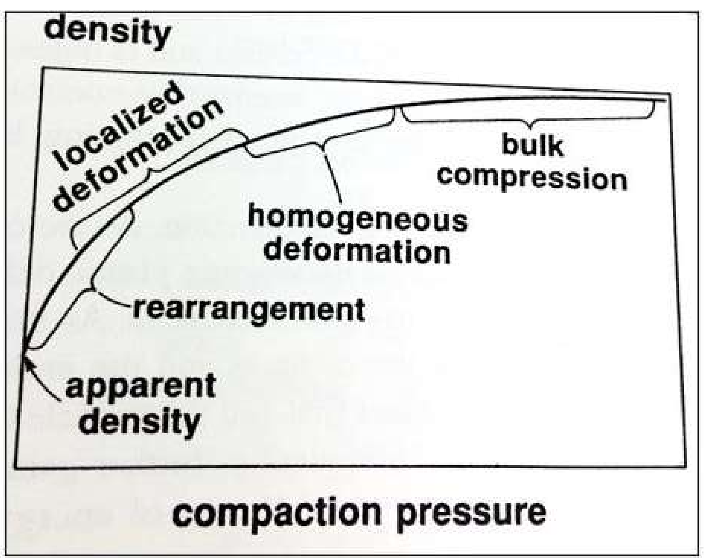

Figure 1: The phenology of powder compaction

The four major mechanisms controlling densification are

- Rearrangement
- localized deformation
- homogeneous deformation

- bulk compression

As pressure is applied, the first response is rearrangement of the particles with filling of large pores, giving a higher packing coordination. Increasing pressure provides better packing and leads to decreasing porosity with the formation of new particle contacts. The point contacts undergo elastic deformation, and at all points in the compaction cycle a residual elastic energy is stored in the compact. High pressures increase density by contact enlargement through plastic deformation. Thus, the pressure causes localized deformation at the contacts, giving work (strain) hardening and allowing new contacts to form as the gaps between particles collapse.

- **Green Strength:** During deformation, cold welding at the interparticle contacts contributes to the development of strength in the compact. The strength after pressing, but before sintering, is termed the **green strength**.

Equipment/ Raw Materials:

1. Powder
2. Lubricant
3. Cotton
4. steel die-punch set
5. powder compaction unit

Powder compaction unit

steel die-punch set

powder

Lab Deliverables:

1. Write a full lab report based on your observations and results.

2. What are the practical precautions required before beginning powder compaction?

Sol:

- Choosing the appropriate type of powder compaction die and pressure according to the desired properties and shape of the final product

- Mixing and blending the powder with suitable additives, such as lubricants, binders, and reinforcements, to facilitate easy ejection, reduce wear, and enhance compressibility.
- Ensuring the cleanliness and dryness of the powder, die, and press to avoid contamination and corrosion.
- Controlling the temperature and atmosphere during the compaction process to prevent oxidation, decomposition, or phase transformation of the powder

3. Differentiate between the functions of a lubricant and a binder.

Sol: Lubricants are used to reduce friction between two surfaces. They do this by creating a thin film between the surfaces that prevents direct contact. Binders, on the other hand, are used to hold particles together. They do this by forming a strong adhesive bond between the particles.

Function	***Lubricant***	***Binder***
Reduces friction	Yes	No
Holds particles together	No	Yes

4. What is the difference between die wall lubrication and powder lubrication?

Sol:

- **Die wall lubrication:** Die wall lubrication involves applying a lubricant to the walls of the die cavity before each casting cycle. This lubricant helps to reduce friction between the die and the molten metal, which can improve the surface finish of the finished casting and reduce the risk of die wear. Die wall lubricants can be either solid or liquid, and they are typically applied using a brush or spray gun.
- **Powder lubrication:** Powder lubrication involves mixing a lubricant powder in with the molten metal before it is injected into the die cavity. This lubricant powder helps to reduce friction between the molten metal and the die, and it also helps to improve the flowability of the molten metal. Powder lubricants are typically made from graphite, molybdenum disulfide, or other materials that have good lubricating properties.

5. Discuss advantages and disadvantages of conventional die compaction.

Sol:

Advantages:

- High production rates: Conventional die compaction can produce large volumes of parts at a high rate, making it a cost-effective process for mass production.

- Good part quality: Conventional die compaction can produce parts with high dimensional accuracy and precision.

- Versatility: Conventional die compaction can be used to produce a wide variety of parts, from simple to complex, in a variety of materials.
- Relatively low tooling cost: The tooling costs for conventional die compaction are relatively low, compared to other manufacturing processes, such as injection molding.

Disadvantages:

- High material waste: Conventional die compaction produces a significant amount of material waste, which can be costly and environmentally harmful.
- Limited part size: The size of parts that can be produced by conventional die compaction is limited by the size of the die.
- Complex tooling: The tooling for conventional die compaction can be complex and expensive to design and manufacture.
- High energy consumption: Conventional die compaction consumes a lot of energy, which can increase production costs and environmental impact.

6. Define green density, green strength, compression ratio densification parameter and ejection pressure.

Sol:

Green density	Green density is the density of a powder metallurgical compact before sintering
Green strength	The strength after pressing, but before sintering, is termed the green strength.
Compression ratio densification parameter	Compression ratio densification parameter is a measure of the densification of a powder metallurgical compact during compaction. It is calculated by dividing the green density by the theoretical density of the material. The compression ratio densification parameter is used to design compaction processes and to predict the green density of a compact
Ejection pressure	Ejection pressure is the force required to eject a powder metallurgical compact from a die

7. What is fill? How do you measure it?

Sol:
Fill in powder metallurgy is the process of filling a die cavity with powder feedstock. It is the first step in the powder metallurgy process, and it is important to ensure that the die cavity is filled completely and uniformly. This will help to produce a high-quality part with the desired properties.

There are two main methods for measuring fill in powder metallurgy:

- Volumetric measurement involves measuring the volume of powder fed into the die cavity. This can be done using a variety of methods, such as a weigh feeder or a volumetric feeder.
- Density measurement involves measuring the density of the powder compact in the die cavity. This can be done using a variety of methods, such as the Archimedes method or the ultrasonic method.

<u>Observations and calculations:</u>

Weight of AL_2O_3 powder: 24.5 g

Volume after tapping:

No. of tappings	***Volume (ml)***
10	28
500	25
750	19
1250	18.5

For AL_2O_3

Bulk density of AL_2O_3	0.875 gm/ml
Tap density of AL_2O_3	1.3243 gm/ml
Compression index	33.93%
Hausner ratio	1.5135

For 8 ton load	
Initially:	
Diameter	15.05 mm
Thickness	5 mm
Weight	1.941 gm
After Sintering	
Diameter	14.67 mm
Thickness	4.05 mm
Weight in air	1.861 gm
Weight in water	1.235 hm

For 6 ton load	
Initially:	
Diameter	15.2 mm
Thickness	4.93 mm
Weight	1.971 gm
After Sintering	
Diameter	14.77 mm
Thickness	4.18 mm
Weight in air	1.847 gm
Weight in water	1.271 gm

Volume of 8 Ton compact: $pi * D^2 * h/4 = 0.684\ cm^3$

Volume of 6 Ton compact: $pi * D^2 * h/4 = 0.716\ cm^3$

Density of 8 Ton compact: mass/volume = 1.81 gm/cm^3

Density of 6 Ton compact: mass/volume = 1.78 gm/cm^3

<u>Conclusion:</u>

Conventional die compaction of Al2O3 Powder was performed using steel die, punch supporting disk and hydraulic press. Uniaxial pressure was applied (single pressing). Loads of 4 tonne, 8 tonne were applied for one minute each. Then ejection pressure is applied to eject the compact from the die. Then the dimensions and green density of the compact was measured. From the observed data we can see that after compaction the green density is greater than the tap density before compaction.