Sintering

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Introduction

Sintering is defined as

The thermal treatment of a powder or compact at a temperature below the melting point of the main constituent, for the purpose of increasing its strength by bonding together of the particles.

Types of Sintering

1. **Solid state sintering**

   Only solid phases are present at the sinter temperature

2. **Liquid phase sintering**

   Small amounts of liquid phase are present during sintering

3. **Reactive sintering**

   Particles react with each other to new product phases

Important Parameters in Sintering

We can divide these parameters into four broad categories

- **Powder preparation:**
  - -- Particle size
  - -- Shape
  - -- Size distribution

Important Parameters in Sintering

- **Distribution of:**
  - -- Dopants
  - -- Second phases
- **Powder Consolidation:**
  - -- Density
  - -- Pore size distribution

Important Parameters in Sintering

- **Firing:**
  - -- Heating rate
  - -- Temperature
  - -- Applied pressure
  - -- Atmosphere

Important Parameters in Sintering

- Some parameters, such as the sintering temperature, applied pressure, average particle size and atmosphere can be controlled with sufficient accuracy
- Others, such as the powder characteristics and particle packing are more difficult to control but have a significant effect on sintering

What Happens During Sintering?

- Atomic diffusion takes place and the welded areas formed during compaction grow until eventually they may be lost completely

- Recrystallisation and grain growth may follow, and the pores tend to become rounded and the total porosity, as a percentage of the whole volume tends to decrease

What Happens During Sintering?

- In the pressing operation the powder particles are brought together and deformed at the points of contact
- At elevated temperature - the sintering temperature - the atoms can move more easily and quickly migrate along the particle surfaces (the technical term is ***Diffusion***)

What Happens During Sintering?

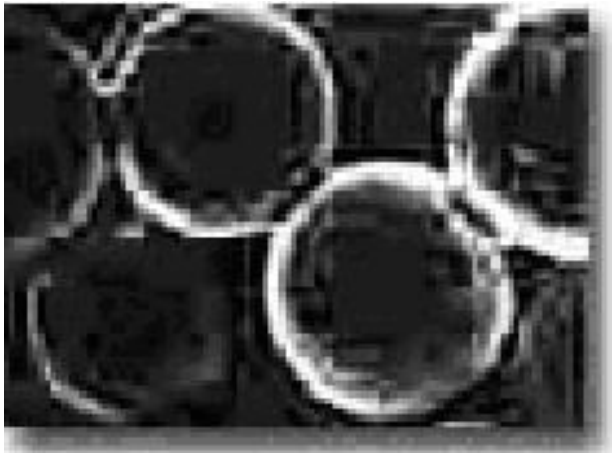
Metals consist of crystallites

- At the sintering temperature new crystallites form at the points of contact so that the original inter-particle boundaries disappear, or become recognizable merely as grain boundaries (This process is called Recrystallisation)

What Happens During Sintering?

- The total internal surface area of the pressed body is reduced by sintering

- ***Neck-like*** junctions are formed between adjacent particles as can be seen on the adjoining scanning electron micrograph



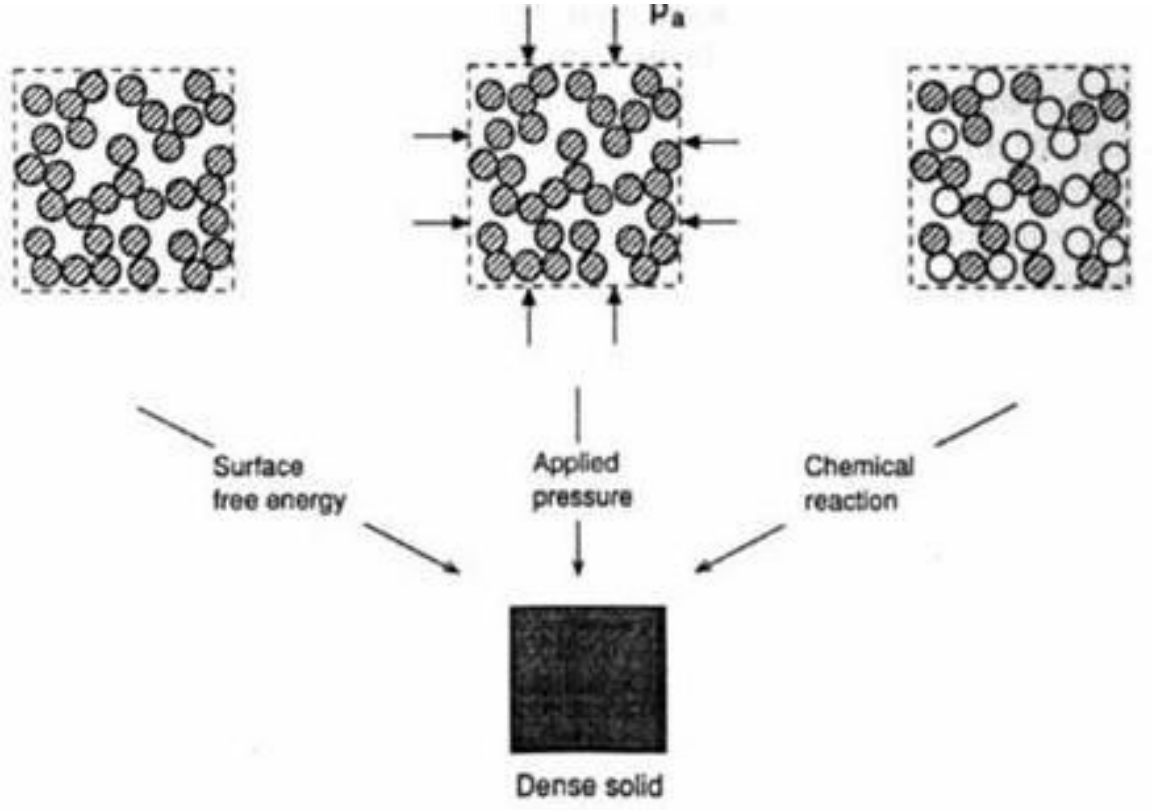
Driving Force for Sintering

As with all processes, sintering is accompanied by an increase in the free energy of the system. The sources that give rise to the amount of free energy are commonly referred to as the driving forces for sintering. The main possible driving forces are

- The curvature of the particle surfaces
- An externally applied pressure
- A chemical reaction

Driving Force for Sintering

Schematically it can be shown as



Stages of Sintering

Three stages are distinguished in sintering

- ***First Stage***

  After burn out of any organic additives, two things happen to the powder particles when the mobility of the surface atoms has become high enough; initially rough surface of the particles is smoothed and neck formation occurs

Stages of Sintering

- ***Second Stage***

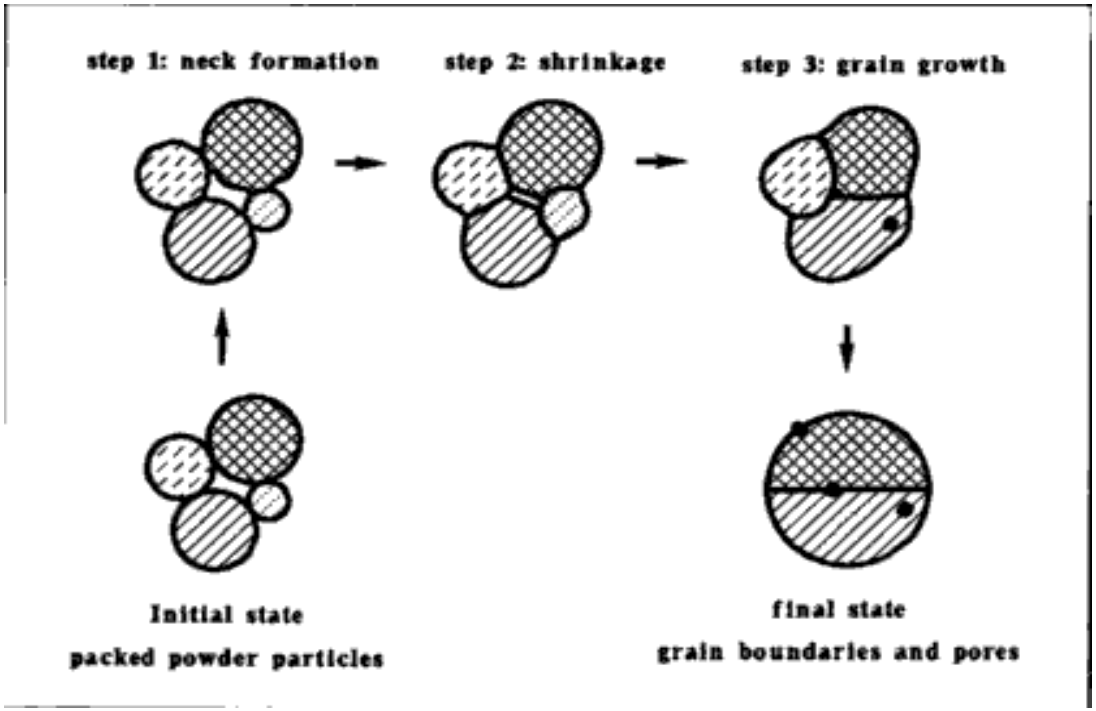
  Densification and pore shrinkage. If grain boundaries are formed after the first stage, these are new source of atoms for filling up the concave areas which diminishes the outer surface of the particle

- ***Third Stage***

  Grain growth takes place, the pores break up and form closed spherical bubbles

Stages of Sintering

The three stages in the dry sintering can be shown as

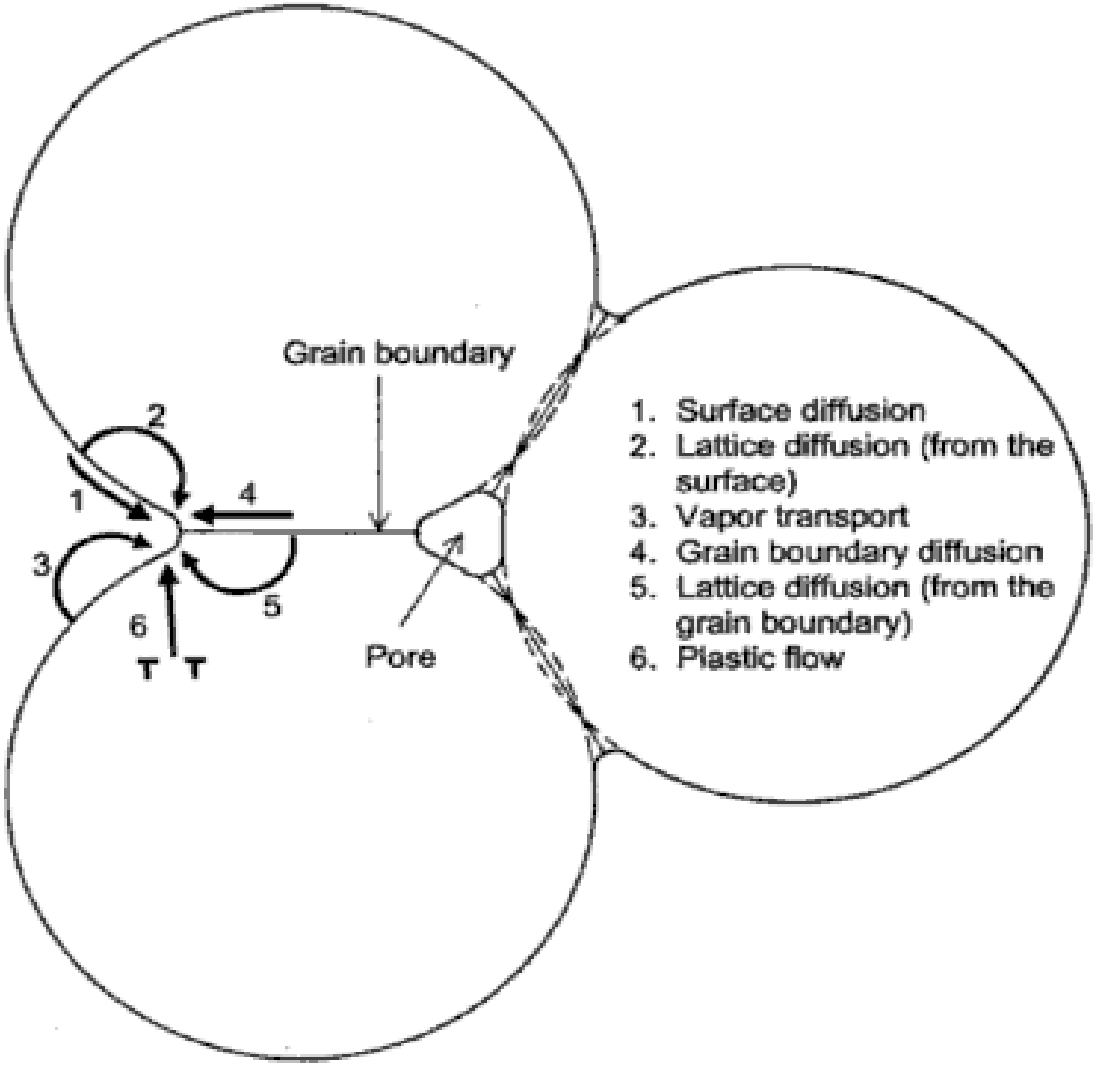


Mechanisms of Sintering

Six mechanisms can contribute to the sintering of a consolidated mass of crystalline particles

1. Surface diffusion
2. Lattice diffusion from the surface
3. Vapor transport
4. Grain boundary diffusion
5. Lattice diffusion from the grain boundary
6. Plastic flow

Mechanisms of Sintering



Advantages of Sintering

Particular advantages of this powder technology include:

1. the possibility of very high purity for the starting materials and their great uniformity
2. preservation of purity due to the restricted nature of subsequent fabrication steps

Advantages of Sintering

3. stabilization of the details of repetitive operations by control of grain size in the input stages
4. absence of segregated particles and inclusions (as often occurs in melt processes)
5. no requirement for deformation to produce directional elongation of grains


Thank You!