

Sintering

Sintering is a manufacturing process in which a fine powder that has been formed into a shape is subsequently fired at temperature below melting point. The compact, when fired, densifies and becomes non-porous . The powder particles form bonds at this temperatures and the contact points between particles, which were originally formed under the mechanical pressure during compaction, increase in size and strength, improving mechanical properties.

sintering is a thermal treatment that densification accompanies it. Densification almost always requires shrinkage. The shrinkage takes place as a result of materials being transported by one or more of several diffusion processes. This may involve a liquid or reactive liquid or diffusion at grain boundaries or through the volume of particle.

Therefore, it is a densification process where porosity is usually reduced and the grain size increases significantly through mass transport. This is important because it allows an engineer to form a dense ceramic body at temperatures below the often very high melting temperature of the ceramic. For many properties such as strength, thermal conductivity, and translucency, in order to reach a maximum value for a product, it is necessary to remove as much porosity as possible. A formed powder compact can be anywhere from 40% to 75% dense, with little strength. A sintered body can have much higher strengths and densities exceeding 99% .

The ability to achieve dimensional tolerances in powder metallurgy parts arises directly from the control of the sintering process and in particular shrinkage. Thus a detailed understanding of the sintering process and the associated shrinkage is of considerable importance.

Sintering Mechanisms

Sintering proceeds from various mass-transport mechanisms. These can be divided into surface transport and bulk transport mechanisms. In surface transport mechanisms, atoms move from the surface of one particle to the surface of another particle. In bulk transport mechanisms, atoms move from the particle interior to the surface. Surface transport mechanisms lead to neck growth without shrinkage or densification, while bulk transport mechanisms result in net particle movement, leading to shrinkage and densification. Densification means an increase in packing density. The surface transport mechanisms are surface diffusion and vapor transport, and the bulk transport mechanisms are lattice diffusion, grain boundary diffusion, and viscous flow. In powders composed of different materials, chemical reactions (also called reactive Process) may also provide additional mass-transport mechanisms .

Different mechanisms dominate at different points in the sintering process, and different materials exhibit different mechanisms. For instance, viscous flow is the diffusion in the liquid phase and evaporation condensation (vapor diffusion) is in the gaseous phase. Evaporation condensation and surface diffusion are called non-densifying mechanisms because they do not contribute to the pore shrinkage. They only increase the cohesion of the grains by the increase of the grain contacts. While other mechanisms contribute to the decrease of the volume fraction of pores; i.e.; the shrinkage .

The compaction powder (called a green compact) has a large surface area relative to its volume. This surface area provides the driving force in sintering, which is the reduction of free surface energy resulting from the high surface area of the particles.

The driving force of the sintering process is the reduction of overall free energy by the decrease of specific surface area and compact interfaces.

Solid state sintering may be performed by two alternative processes: One reduction of the total surface area by an increase in the average size of the particles, which leads to coarsening Figure 3-3b, and/or to the elimination of solid / vapor interface and the creation of grain boundary area, followed by grain growth, which leads to densification Figure 3-3a.

These two mechanisms are usually in competition. If the atomic processes that lead to densification dominate, the pores get smaller and disappear with time and the compact shrinks. But if the atomic processes that lead to coarsening are faster, both the pores and grains coarsen and get larger with time .

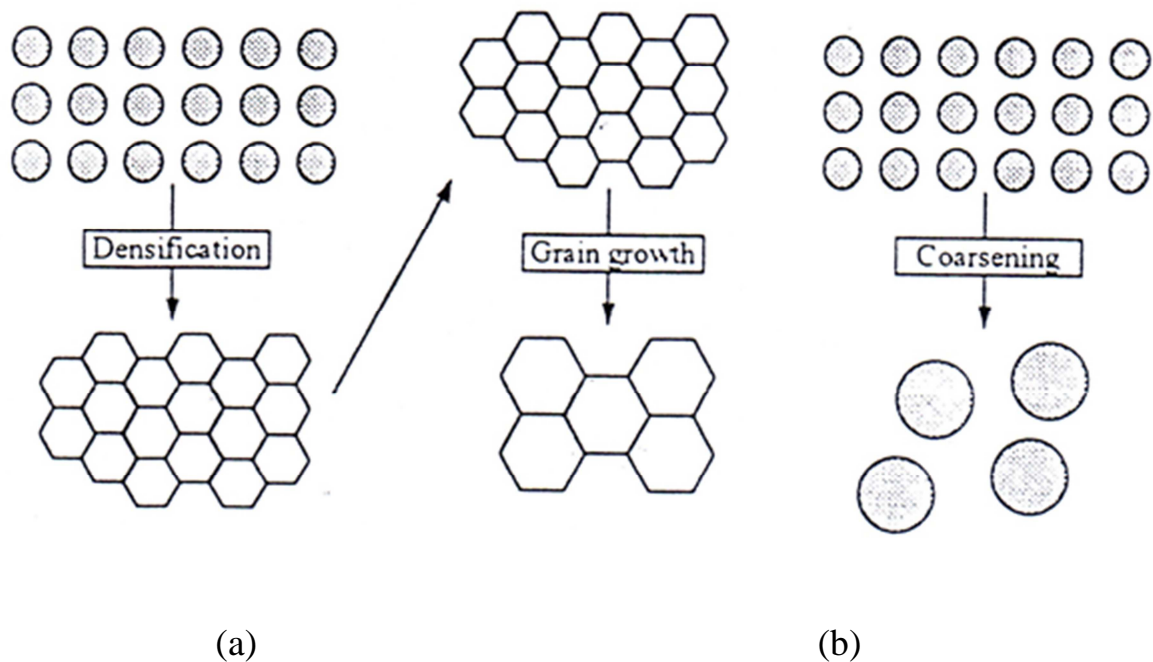
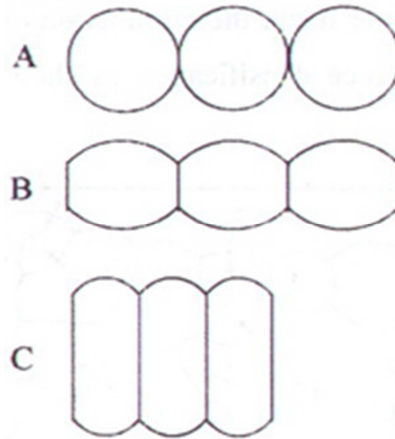


Figure (1-3) schematic of two possible paths by which a collection of particles can lower its energy .

Figure 3.3 shows neck growth with no shrinkage for simple array of spherical particles when the operating mechanism is a surface or vapor

diffusion only. When a densifying mechanism is operating, both neck growth and densification takes place as shown in the same figure .



Figure(3-4) A. row of initially spherical particle
B. neck growth and no shrinkage by surface or vapor phase diffusion.
C. the shrinkage when a densifying mechanism is operating .

A sintered part begins as a compact, which is a powder placed into a mold or die cavity. The green compact is low-density, inhomogeneous and porous, and generally lacking in physical integrity. There is, however, a small degree of adhesion between adjacent particles .

Sintering can occur either at atmospheric pressure or under isostatic or hydrostatic pressure. This pressure-assisted sintering increases the sintering rate, reduces sintering time, and reduces porosity in the final part. It generally takes place at temperatures in excess of half the absolute melting temperature. If sintering takes place at temperatures high enough that some melting occurs, it is called liquid-phase sintering; sintering that takes place at lower temperatures is called solid-state sintering .